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EVALUATION OF AN ADVANCED WIND/DIESEL HYBRID FOR REMOTE CANADA

PREPARED FOR:

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Energy, Mines and Resources Canada
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Résumé

On admet, depuis plus de dix ans, qu'il existe au Canada de grandes possibilités quant à l'utilisation de l'énergie éolienne dans certains endroits où l'électricité est actuellement produite à partir du diesel. On s'est en outre rendu compte que sur le plan économique et technique, il serait plus pratique d'exploiter des systèmes hybrides permettant une utilisation optimale de l'énergie éolienne et de l'énergie produite au moyen du diesel dans les endroits très exposés au vent. Reposant sur l'exploitation d'une source de production classique, soit le diesel qui leur assure une autonomie totale, de tels systèmes permettront de réduire les frais d'entretien et de réaliser des économies de combustible grâce l'intervention d'une source d'énergie propre et renouvelable. Dans de nombreuses régions éloignées, ces économies seront telles qu'il sera possible de réduire considérablement les volumes de combustibles transportés et stockés, et donc de diminuer les risques pour l'environnement et les frais de transport.

Toutefois, on n'a pas encore réalisé tous les objectifs des systèmes hybrides éolien/diesel bien qu'on ait réussi à résoudre certains des problèmes techniques qui se sont posés. Des systèmes hybrides éolien/diesel sont actuellement exploités partout dans le monde, notamment au Canada.

Le projet avait pour but d'évaluer un nouveau concept en matière de système hybride éolien/diesel de grandeur modeste. Il s'agit d'un système perfectionné qui se fonde sur l'électronique de puissance moderne, notamment sur des systèmes de contrôle à microprocesseurs à haut rendement et sur des convertisseurs à transistor MOS. Ce système repose sur l'utilisation d'une ou de plusieurs éoliennes pour charger une batterie d'accumulateurs et la synchronisation de la puissance fournie par un convertisseur c.a. et un ou deux groupes générateurs diesel pour la production continue d'énergie électrique de type réseau. En outre, il fait plein emploi de l'énergie éolienne disponible et profite au maximum de la capacité de production du système diesel, quelle que soit la charge à un moment donné.

Le système perfectionné se fonde sur des systèmes diesel à charge cyclique, dont la fiabilité n'est plus à prouver, et sur des systèmes hybrides éolien/diesel existants à charge cyclique. Il représente une amélioration subtile mais importante par rapport aux systèmes à charge cyclique existants, car il promet une réduction sensible des coûts des premiers investissements, du volume de combustible utilisé et des frais d'entretien. Un tel système perfectionné peut s'avérer très important pour le Canada où la nouvelle technologie pourrait être intégrée aux groupes diesel exploités en permanence. L'étude examine un modèle d'installation et en analyse le fonctionnement en se fondant sur des renseignements historiques fournis pour un modèle de site, afin d'évaluer les aspects technique, opérationnel et économique du nouveau concept. Elle présente aussi une analyse qualitative des éventuels avantages environnementaux.

Le projet complète et étend la portée des travaux en cours autorisés par le Centre

d'essais éoliens de l'Atlantique (CEEA). Par conséquent, on présentera au CEEA le rapport sur les travaux entrepris, sur les recommandations formulées et sur les travaux futurs qui découleront du projet et, au besoin, on coordonnera ces activités avec le Centre.

1.0 Introduction

It has been recognized for over a decade that there is great potential in Canada for the use of wind energy in locations where diesel generation of electricity is currently in use. A part of this recognition has included the realization that hybrid power supply systems making the optimum use of wind energy and diesel generation would make the most economic and technical sense for locations where wind resources are available. Such systems provide full stand-alone capability with the diesel system, using a conventional generation source, and provide the promise of fuel and maintenance savings using clean, renewable energy. In many remote circumstances, the fuel savings translates into important fuel transportation and storage reductions, which reduces environmental hazards as well as freight costs.

However, the goals of wind/diesel hybrid systems have not yet been fully realized, though the technical problems which have arisen are being overcome successfully in some instances. Around the world, and in Canada, wind/diesel systems have been, and are, operating.

This work is to evaluate a new concept in modest sized wind/diesel hybrid systems, which makes use of modern power electronics, particularly high speed microprocessor based control systems and MOSFET inverter technology. The system is an advanced wind/diesel hybrid, based on the use of one or more wind turbines to charge storage batteries, and the synchronization of an AC inverter output with one or two diesel generating sets, to provide full-time utility grade power making full use of available wind energy, and fully optimized use of available diesel generation capacity, regardless of loads at any time.

The advanced system builds on past success with diesel cycle-charging, and existing installations of wind/diesel cycle charging applications. The advanced system is a subtle, but important and major improvement over existing cycle charging systems, because it promises the ability to reduce initial capital costs considerably, provide significant further improvements in fuel savings and maintenance costs, and - perhaps very significant in Canada - the advanced system provides the opportunity to retro-fit existing full-time diesel sites with the new technology. This study makes use of an example design, and an analysis of its operation using historical information for an example site, to evaluate the new concept from a technical, operational and economic perspective. A qualitative examination of environmental benefits which may result is also performed.

This work complements and enhances the work under way and mandated by the Atlantic Wind Test Site [AWTS] in Canada. With that in mind, the work conducted, and recommendations and follow-on work which arise from this project will be reported to and, if warranted, coordinated with AWTS.

1.1 Background

Many of Canada's remote sites which rely on diesel generation and are located in regions which have useful wind energy resources are not large communities. For example, a significant number of applications in the Canadian Arctic are less than 100 kW in capacity[1]. Conventional, 'no-storage' AC grid wind/diesel hybrid systems often base the ratio of wind energy capacity (based on nameplate rating) to diesel generation output (at typical load conditions) in the 30 to 50% range, maximum, to prevent power quality problems. Such 'penetration' levels reduce fuel use somewhat in diesel engines, but do not have significant impacts on maintenance and fuel costs; in fact, there is a risk that the high penetration and resulting low loading on operating diesels may increase maintenance and repair costs. Other AC grid wind/diesel systems use sophisticated controls and short term storage systems to maintain frequency and voltage, while turning off diesel units for periods of time; again, diesel manufacturers are not happy about numerous start/stop cycles.

Smaller wind/diesel hybrid systems, particularly those in the 10 to 20 kW size range and under, are usually based on a cycle-charging storage battery system. These systems typically make use of a wind turbine to capture available wind energy, store the energy in battery systems, and produce AC power for a wide variety of uses through a static inverter. The diesel is often a back-up unit, but may be the prime mover, or may share such a role with the turbine as 'fuel' is available. A typical such a system is supplemented with a fossil fuel generator and battery charger, with a transfer switch system, which provides power for additional loads and/or charge the batteries when insufficient wind energy is available.

These hybrid cycle-charging systems are based on existing cycle-charging system designs powered solely from fossil fueled generators, such as diesel, gasoline or propane fueled gensets. Cycle-charging genset systems increase the efficiency of a power supply system considerably, relative to full-time genset operation. They typically are limited in size, however, due to the costs associated with batteries and inverters, or they must be designed to operate the genset very often in order to avoid large batteries. There is a cap on savings, then, due to the cost-benefit aspects of balance of system components versus fuel and maintenance savings.

One method of approach has been used by Nor'wester Energy Systems for remote residential applications. One typical system supplied by Nor'wester uses a small propane-fueled generator with electric start, a control system with automatic transfer switch, programmable genset controller, and supervising controller with alarms and adjustable set points. AC power is delivered from the genset when it is operating, or from inverters when the system is on battery operation. High efficiency solid state battery chargers are used to charge the batteries from the genset. The operational strategy is that the supervising controller monitors battery voltage and initiates generator operation when voltage drops. After genset warm up, the transfer switch moves all AC loads to the genset, then begins moving battery charging loads to the genset as capacity allows. When the batteries are fully charged, the transfer switch moves back to the inverters, and the genset is shut down. The batteries are charged for about 5 hours every 3 to 4 days in this system. The system is designed to allow 'plug-in' photovoltaic or wind turbine DC sources, which would extend the times between genset operations and further reduce fuel and maintenance costs.

Another method of approach to the cycle-charging genset in Canada is the Mechron CC4000 series. In the Mechron design, batteries are specified for approximately one day's energy needs. Many applications from Mechron are to supply solely DC loads, and no inverters are needed. For AC applications, an inverter is used to supply AC loads from the batteries. Early versions of this diesel-based system used rotary inverters driven by DC motors, but later versions (approximately twenty systems have been delivered) use solid state electronic inverters. When battery voltage drops to a pre-set level, one of the two diesel gensets is activated automatically. Each diesel supplies 3Ø electricity which is stepped down to nominal 48 VAC through a transformer, then rectified and passed through a current limiting battery charging circuit to the batteries. The Mechron system does not use a transfer switch to move the AC load from the inverter to the genset, but leaves the AC load on the inverter and charges the batteries only. Typical designs are set up to operate the diesel 2-3 hours daily. Mechron has had success mating this system to photovoltaic alternate DC power sources, but has not supplied working systems with wind turbines supplementing the system. All of the systems supplied to date have been turn-key type, inclusive of diesels, fuel tanks, etc; the system has not been available to retro-fit existing sites.

The advanced hybrid system uses a new concept, building upon the above system approaches, and promising additional benefits including greater fuel savings, reduced capital costs, greater power peaking capability, retro-fit capability. The main operating feature of this system is the ability to operate the inverter and a diesel generation system **concurrently**, in a synchronized manner, to seamlessly supply the required loads. With this capability, the addition of alternate energy sources is also easily accomplished. With this system operating on diesel generation supply alone, it is theoretically possible to supply peaks to the total of 110% of the diesel capacity, and 200% of the inverter capacity, for a total of 310% of rated output (based on diesel nameplate rating and inverter nameplate rating, and assuming the batteries have at least minimum state of charge at the time). It is anticipated that total normal load capability for a hybrid system incorporating a wind turbine will be up to 60 kW, with peaking for short periods of over 100 kW. A major benefit of this is the ability to supply growing or future load requirements at a site without having to replace existing diesels and other equipment.

The advantages of the system have been stated as including:

- near optimum efficiency of overall system
- efficient operation of the diesel at all times running
- the possibility of using smaller diesel gensets for new installations, decreasing fuel use and increasing efficiency
- the need for much smaller battery banks compared to conventional cycle-charge designs
- easy integration of renewable energy sources into the system.

This study, then, evaluates the advanced wind/diesel hybrid as:

- a hybridized-with-wind cycle charging system with advanced control capability
- a cycle-charging system with new synchronizing and peaking capability
- a system which can be retro-fitted to existing site facilities to save fuel and increase environmental benefits.

This work is intended to examine a realistic and difficult application of this concept, at an extreme case site, where realistically such a system may well be installed in the future. The example site is remote, has high quality windspeed and meteorological records, and currently uses diesel generation; the operators are interested in exploring options which will reduce costs and environmental effects.

In this sense, this work, together with a future monitored evaluation of the equipment installed and operating, provides results which have real application in Canada, with very real and possible follow-on commercial opportunities. The benefits, in terms of cost savings, increased commercial activity, and in environmental benefits, are hoped to be substantial.

1.2 Activity

The project was started in March, and included liaison with the agencies which are associated with the site, and with the technologies involved: Canadian Parks Service [CPS], Atmospheric Environment Service [AES], Energy, Mines and Resources Canada [EMR] and Transport Canada. Site evaluation, assessment of the site for equipment, collection of existing data and initial system design were conducted during this time, however a scheduled trip to the Cape St. James site was delayed due to weather and available air transportation until May 6.

During April, information on loads, climatological data sources, and design information were assembled and processed. The hindcast analysis tools were designed, entered into the computer system, and tested.

In May, the site was visited, load information was verified, detailed load records were made, a full loads inventory was conducted, and the hindcast analyses were initiated.

During June, the analysis was completed, with all information entered into the computers, the hindcast analysis tested with actual data, and all analyses conducted. Results were tabulated and graphed, and reporting conducted. A brief preliminary activity document was prepared for presentation at the International Wind/Diesel Workshop, held in Vermont in late June. The draft Final Report was delivered to EMR for comments.

2.0 Site

2.1 Location

The Cape St. James weather station is located on St. James island at the extreme southern tip of the Queen Charlotte Islands off the west coast of British Columbia (Figure 1), at latitude 51° 56' N and longitude 131° 01' W.

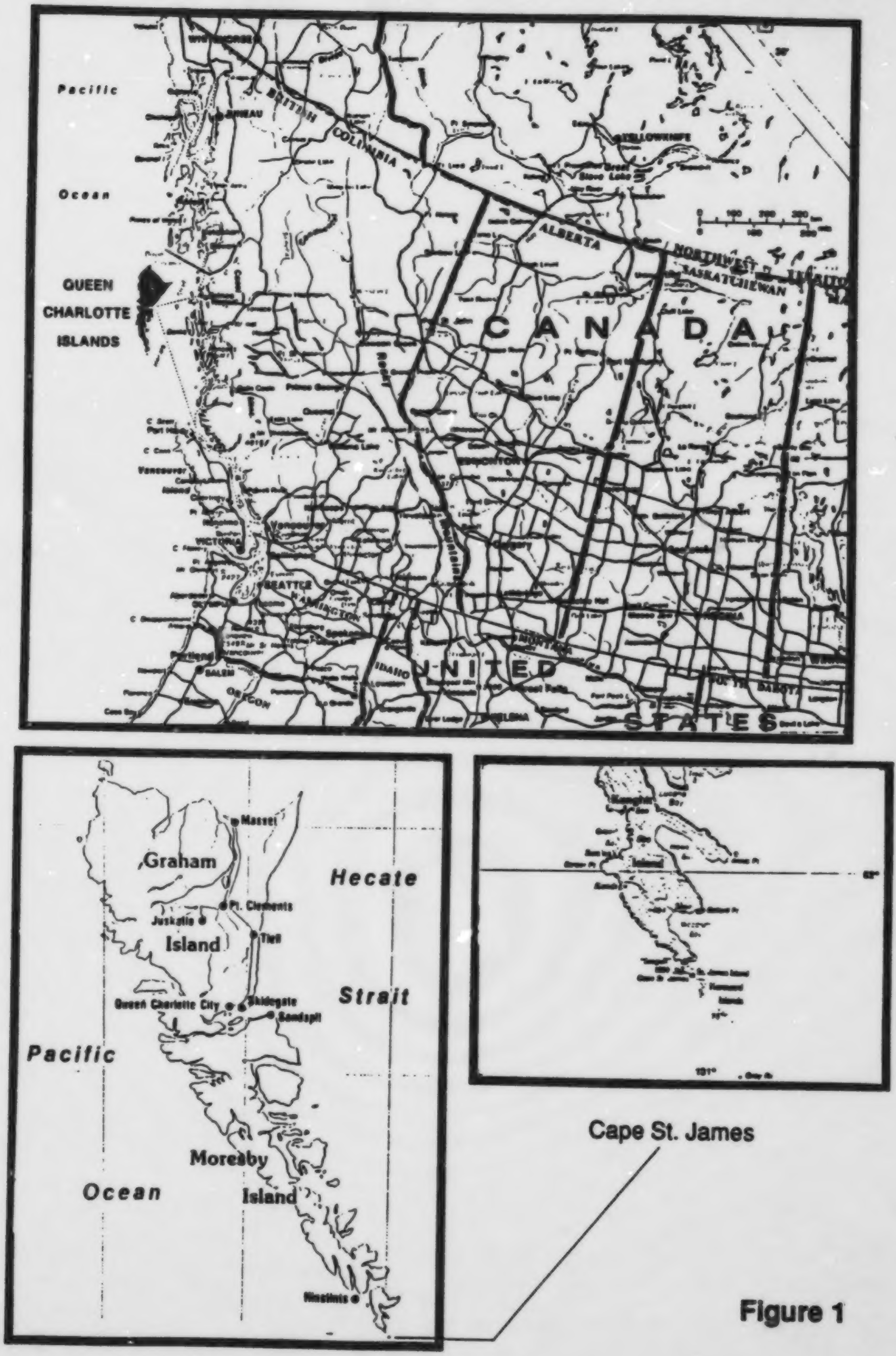
2.2 Layout and Facilities

The weather station and accompanying facilities occupy nearly all of the usable space on the island. The island rises over 75 metres out of the sea and is steeply sided. A tiny bay exists on the east side of the island which is used as a fair weather harbour facility for the site. The layout of the facilities are given in Figure 2. Not shown in the figure are the walkways and stairs that are required to link the various buildings and equipment. The tramway is used to transport heavy items to and from the helipad. The weather station itself is located at the highest point of the island.

The facilities at the peak of the island include the weather station with accompanying instrumentation and an instrument tower which also serves as the support structure for the radio and light beacons located here.The top of this tower is approximately 14 metres A.G.L. A well anchored satellite dish and the tramway winch building are also located here. Further down the north slope of the island is a radio tower which supports one end of the radio antenna (the other is supported on the instrument tower).

Approximately halfway down from the peak to sea level is the station residence, a duplex building with two kitchens and facilities, two living rooms, etc. The helipad and a storage building are also located at this level.

The remaining facilities are located at the harbour level. The generator building is equipped with two 37.5 kVA Perkins diesel genset and a smaller Allis-Chalmers diesel with all necessary switchgear and monitors. The pump shed contains the pumps for transporting diesel fuel to the generator shed from the storage tanks located at the water's edge. Other pumps located here transport heating fuel to the small tanks located at the other site buildings and water to and from the desalination unit located outside the pump shed. A boat winch assembly is located here for lifting the site boat in and out of the water and can also be used for unloading supplies as necessary.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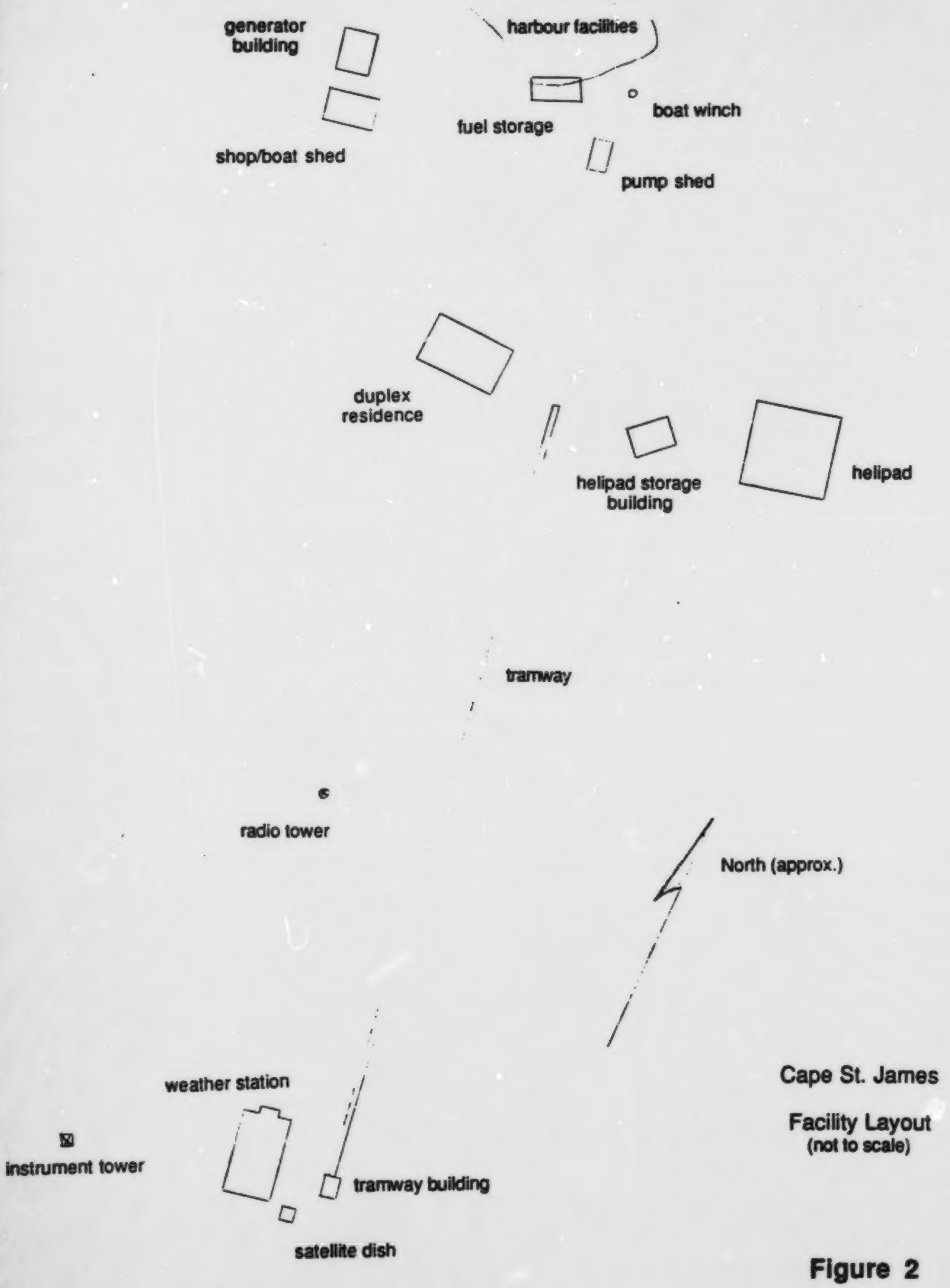
Cape St. James
Cape St. James

Figure 1



Cape St. James

Facility Layout
(not to scale)

Figure 2

3.0 Loads

3.1 Inventory

A load inventory was performed during the site visit. Table 1 lists the results of that inventory. During the inventory, loads that were essential were noted as well as those which could be reduced if it were not necessary to keep the diesel loaded (ie. if a hybrid system were installed). A review of the inventory and discussions with on-site staff indicated that the loads could easily be reduced to 60% of the present loads. The majority of the non-essential loads which could be reduced are lighting loads. Other loads such as the tramway are significant in size, but their use is very limited or occasional. There are typically three personnel on site, there are also three fully equipped kitchens. Obviously a concerted effort to reduce and manage loads would result in significant load reductions.

3.2 History

Records of diesel operation, servicing, etc. are kept on a daily basis. These include daily energy consumption. A complete set of records was obtained from the Atmospheric Environment Service for the study year (see Section 4.0). Appendix A contains the load records for the study year. The daily energy consumption for the study year is shown in Figure 3.

In order to identify the detailed diurnal load use pattern, monitoring was set up during the site visit. A Dranetz 808 Power Monitor was used to record average demand for each fifteen minutes. The monitoring was performed over the period of May 6 to June 1, 1991. The results of this monitoring are given in Figures 4 and 5. It was decided to use the load use pattern of a typical day rather than an averaged day in the hindcast analysis. Since changes in loads do not occur at the same time each day, averaging would have the effect of removing the variations and producing a smooth curve. This would not represent a realistic load pattern. Another option would be to determine averages and standard deviations for each hour and to generate random loads within the bounds of the standard deviation. Little would be gained from using this method rather than a typical day.

The diurnal load variation for a period with the most complete load data was plotted (Figure 6). From this, a day (May 19) most typical of the pattern was chosen (Figure 7). The percentage hourly contributions to the total daily power consumption were then calculated.

TABLE 1

Cape St. James Load Inventory

Building	Load Name	Power (W)	Essential?	Typically on?	Typical Hours/day	Typical load (kW)	Load management Hours/day	Load management load (kW)
Diesel Building	Main lights	960	no	yes	24.00	23.04	0.50	0.48
	Vent motors	188	yes	no	0.25	0.05	0.25	0.05
	Emergency light set	50	yes	yes	24.00	1.20	24.00	1.20
	Shop lights	480	no	no	0.50	0.24	0.25	0.12
	Power Tools	563	no	no	0.50	0.28	0.25	0.14
Boat Building	Paint Room lights	200	no	no	0.25	0.05	0.25	0.05
	Paint Room Heater	500	seasonal	no				
	Boat Room lights	480	no	yes	24.00	11.52	0.25	0.12
Deck Area	Crane	1092	no	no	0.25	0.27	0.25	0.27
	Fuel pumps	1125	no	no	0.25	0.28	0.25	0.28
	Other pump	1500	no	no		0.00		0.00
	Desalination Unit	750	yes	yes	6.00	4.50	6.00	4.50
	Shack Heater	3000	seasonal	no				
	Shack lights	160	no	no	0.25	0.04	0.10	0.02
Lower Walk Lites		900	no	yes	18.00	16.20	1.00	0.90
Ascending Walk Lites		1200	no	yes	18.00	21.60	1.00	1.20
Living Quarters	Electric Stove	4000	yes	no	0.67	2.67	0.67	2.68
	Regrigerators	880	yes	yes	8.00	7.04	8.00	7.04
	Microwave	1500	no	no	0.50	0.75	0.50	0.75
	Freezer	450	yes	yes	8.00	3.60	8.00	3.60
	Washer	600	no	no	0.25	0.15	0.25	0.15
	Dryer	5000	no	no	0.50	2.50	0.50	2.50
	Heating	750	yes	yes	12.00	9.00	12.00	9.00
	U/V water treatment	50	yes	yes	24.00	1.20	24.00	1.20
	Lights	900	no	yes	8.00	7.20	4.00	3.60
Upper Building	Electric Stove	4000	yes	no	0.67	2.67	0.67	2.68
	Regrigerators	880	yes	yes	8.00	7.04	8.00	7.04
	Freezer	450	yes	yes	8.00	3.60	8.00	3.60
	Microwave	1500	no	no	0.50	0.75	0.75	1.13
	Dishwasher	1200	no	no	1.00	1.20	1.00	1.20
	Coffeemaker	900	no	yes	18.00	16.20	3.00	2.70
	Appliances	1500	no	no	0.50	0.75	0.50	0.75
	Misc (TV, radios)	500	yes	yes	24.00	12.00	12.00	6.00
	Instruments etc	750	yes	yes	24.00	18.00	24.00	18.00
	Computers etc	500	yes	yes	24.00	12.00	24.00	12.00
	U/V water treatment	50	yes	yes	24.00	1.20	24.00	1.20
	CCG Radio Beacon	1000	yes	yes	24.00	24.00	24.00	24.00
	CCG Light	750	yes	yes	24.00	18.00	24.00	18.00
Tramway		7500	no	no	*occasional use only*			
Totals		48757			359	231	246	138

Actual Daily Energy Consumption (kWh) 1989 to 1990

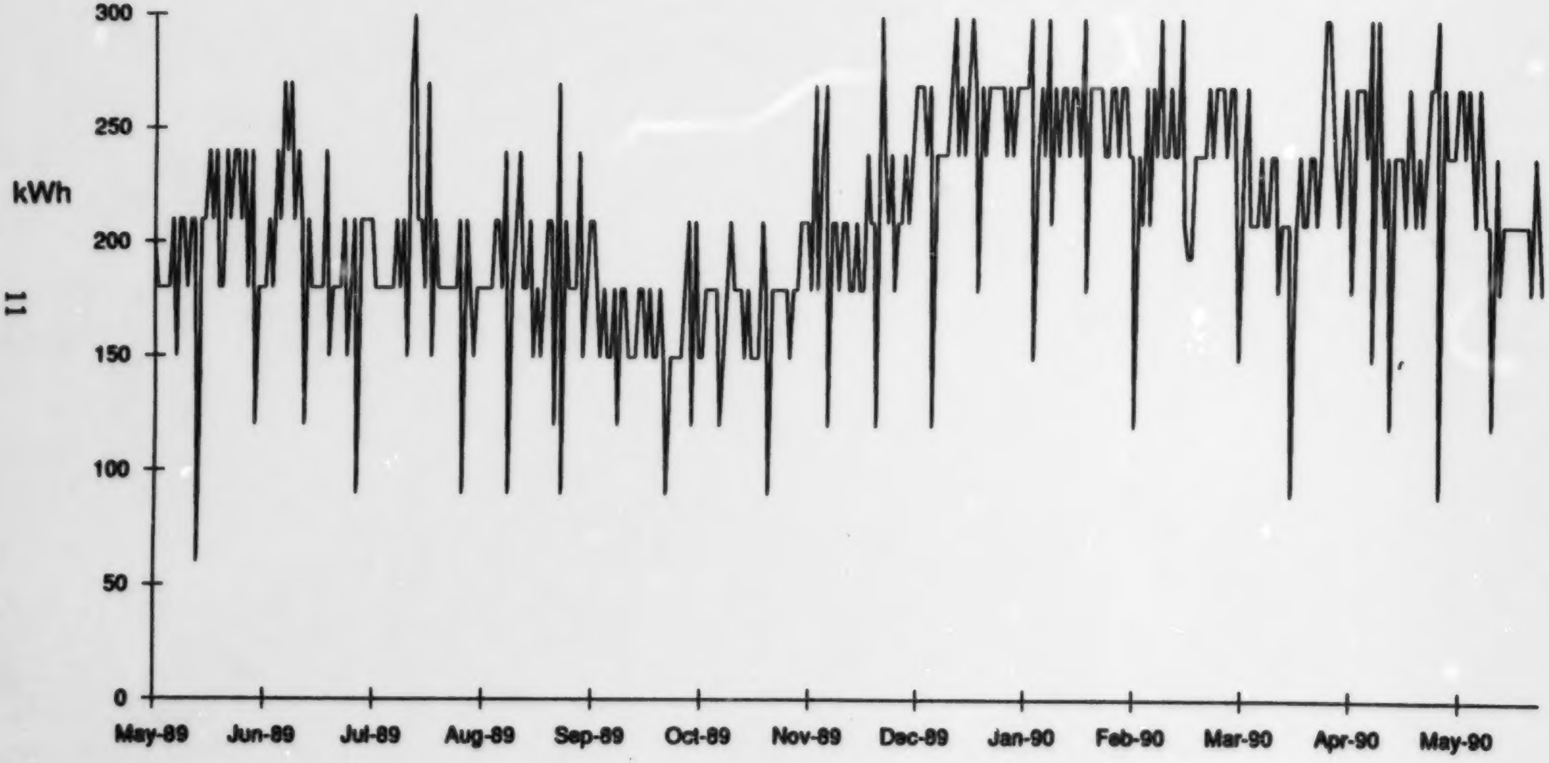


Figure 3

Cape St. James Recorded Loads (May 6 - May 18. 1991)

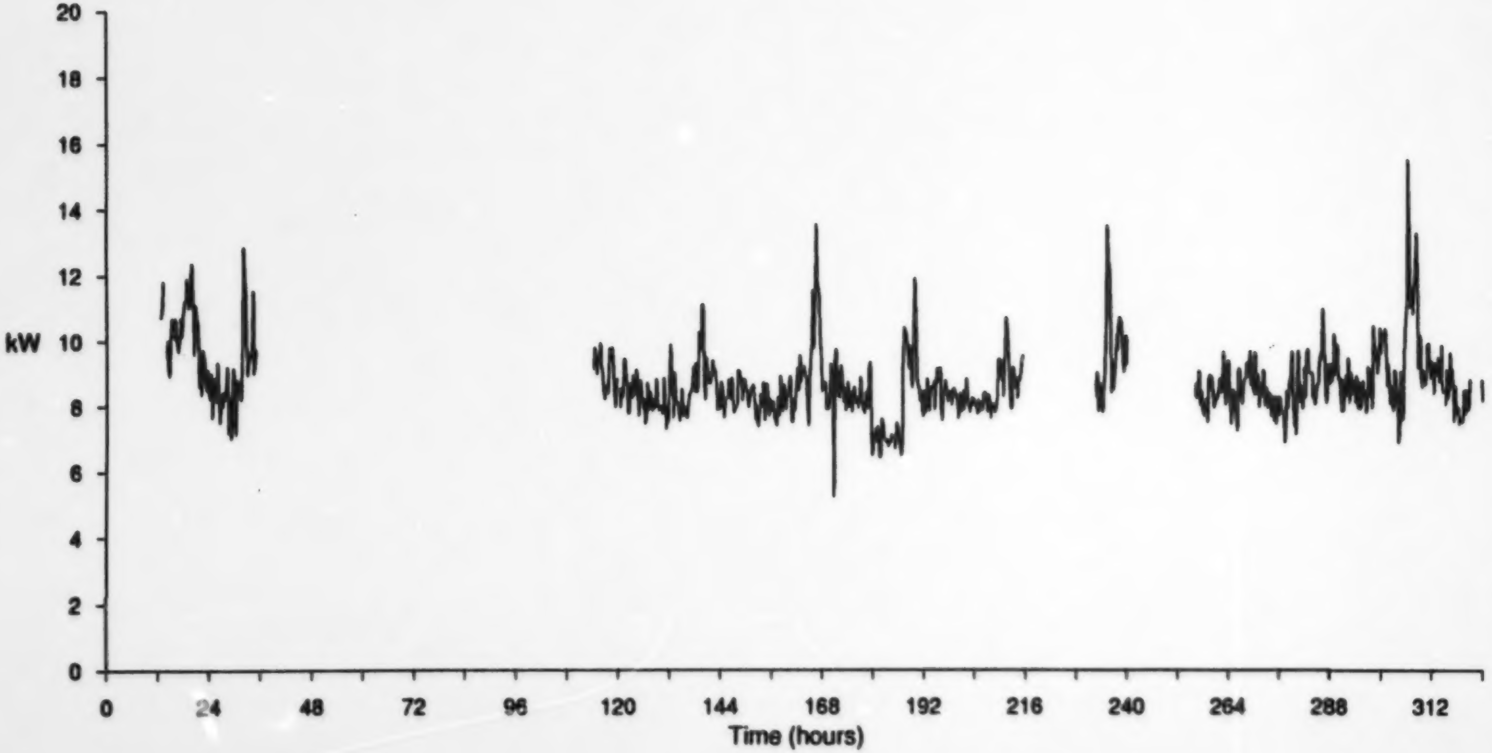
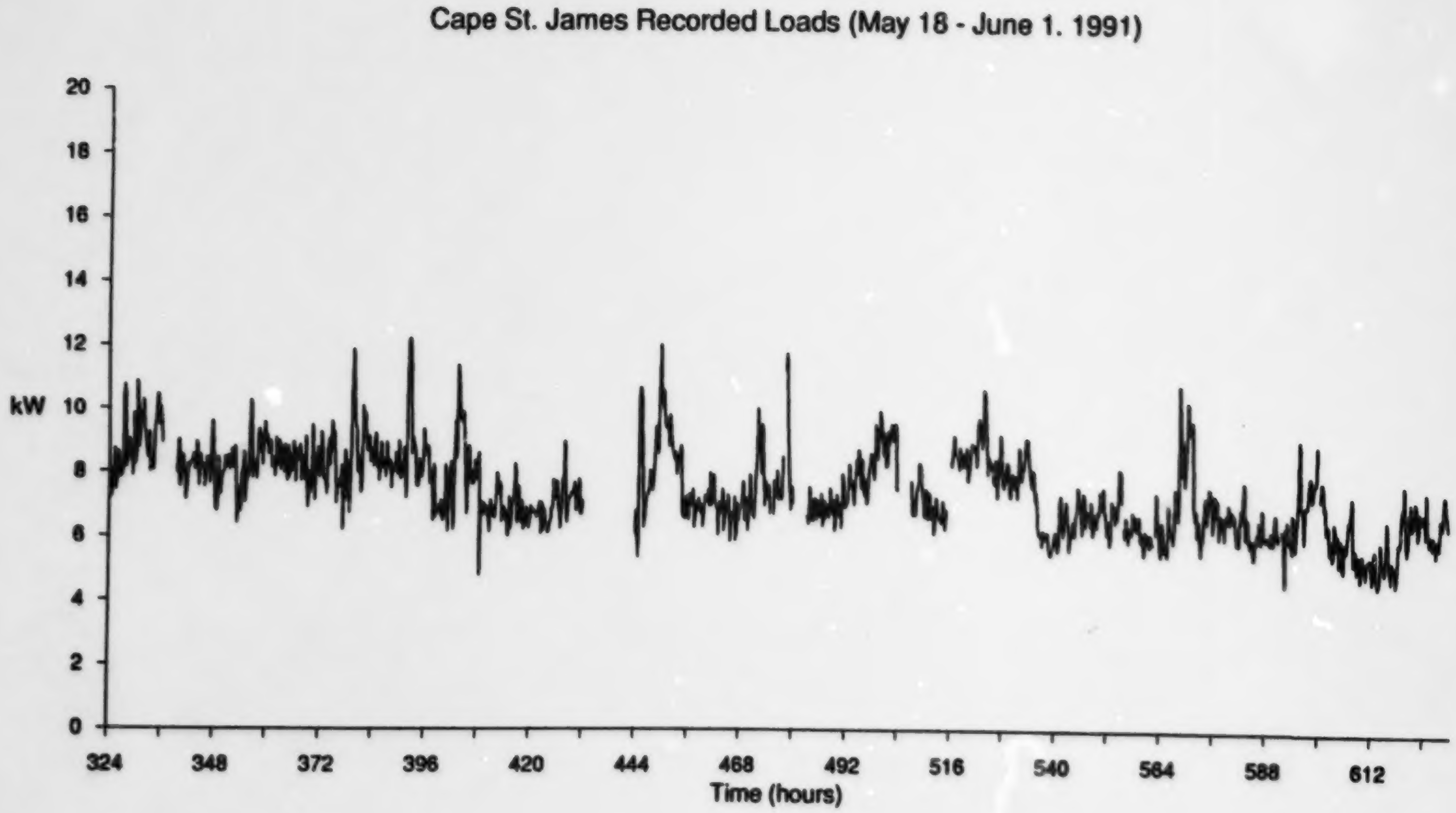


Figure 4



Cape St. James Recorded Loads (May 18 - June 1. 1991)

Figure 5

Cape St. James Recorded Diurnal Load Variation (May 16 - 20, 1991)

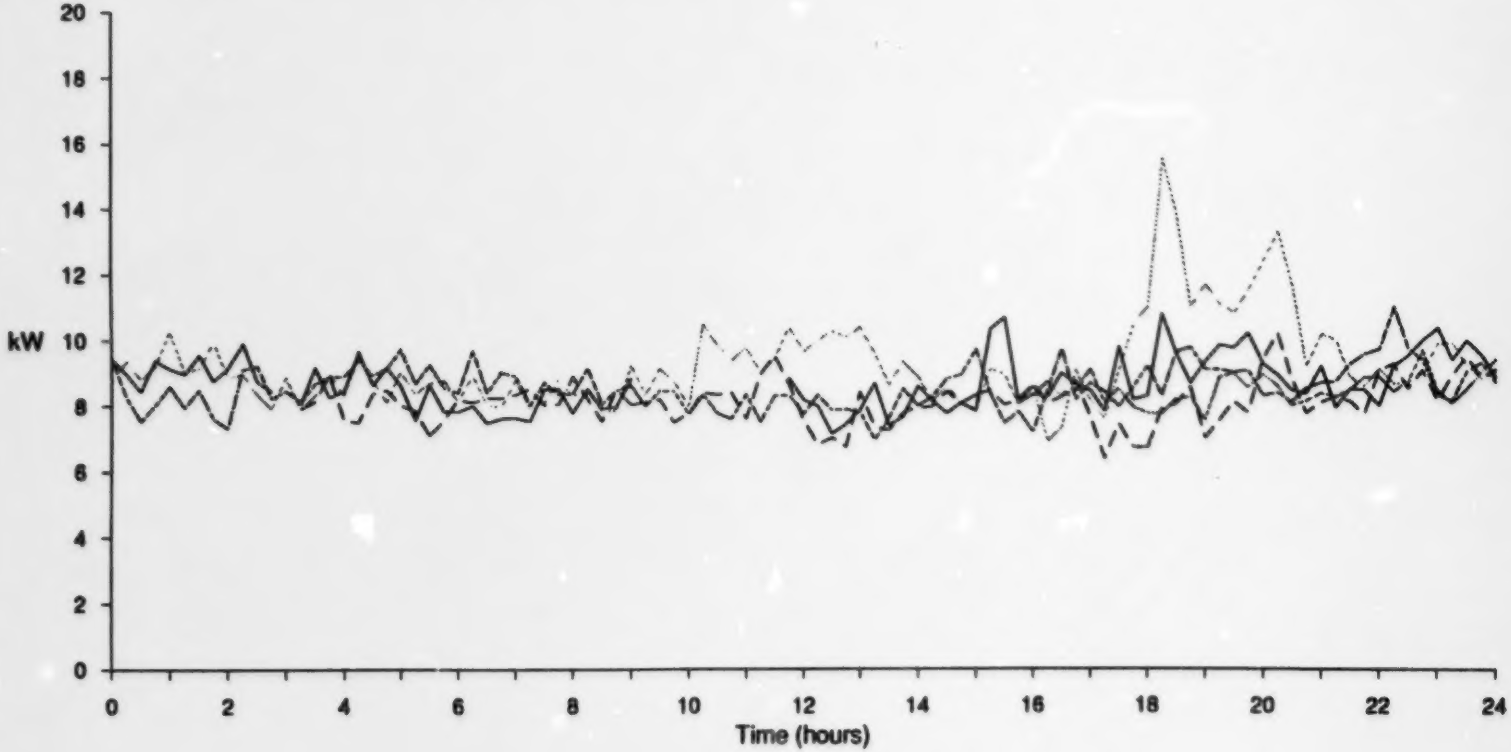


Figure 6

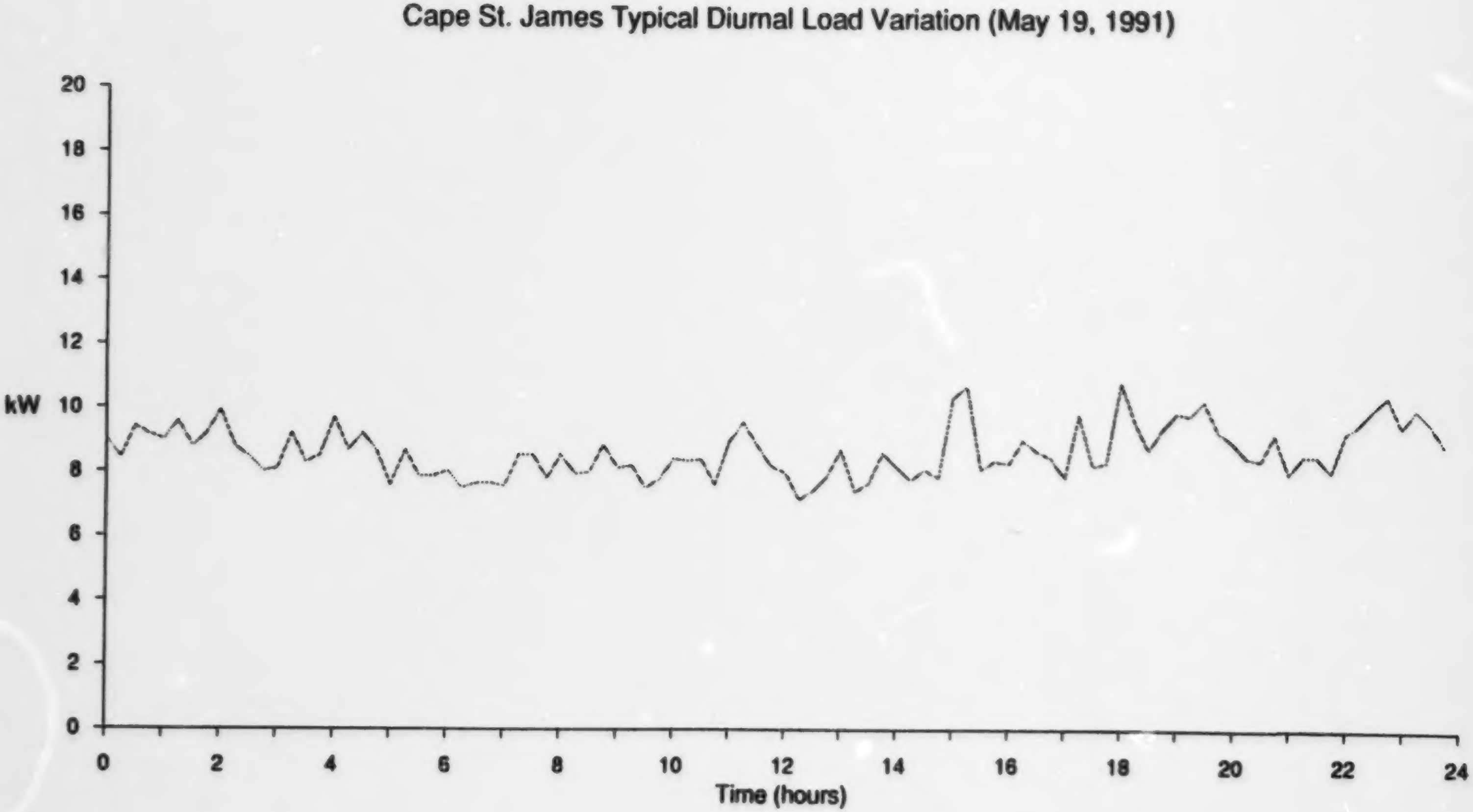

Cape St. James Typical Diurnal Load Variation (May 19, 1991)

Figure 7

These values were used as load factors in the hindcast analysis to generate hourly demands from the actual daily load data.

Load values, assuming that load management would be effected if a hybrid system were installed, were simply taken as 60% of the actual loads.

During the course of this work it was learned that the Cape St. James site is being considered for automation. This would substantially reduce the loads. A standard automatic weather station, a radio beacon and light would be the only equipment operated on site. From discussions with Atmospheric Environment Service personnel and Coast Guard engineers it appears that the continuous load of an automatic station would be approximately 1.6 kW. This figure was used for an additional study outside the primary scope of work, to conduct a hindcast analysis of the site assuming it was automated. Additional loads were added once a month: it was assumed that there would be a servicing and inspection trip on the second Wednesday of each month (similar to the monthly food charter that presently exists).

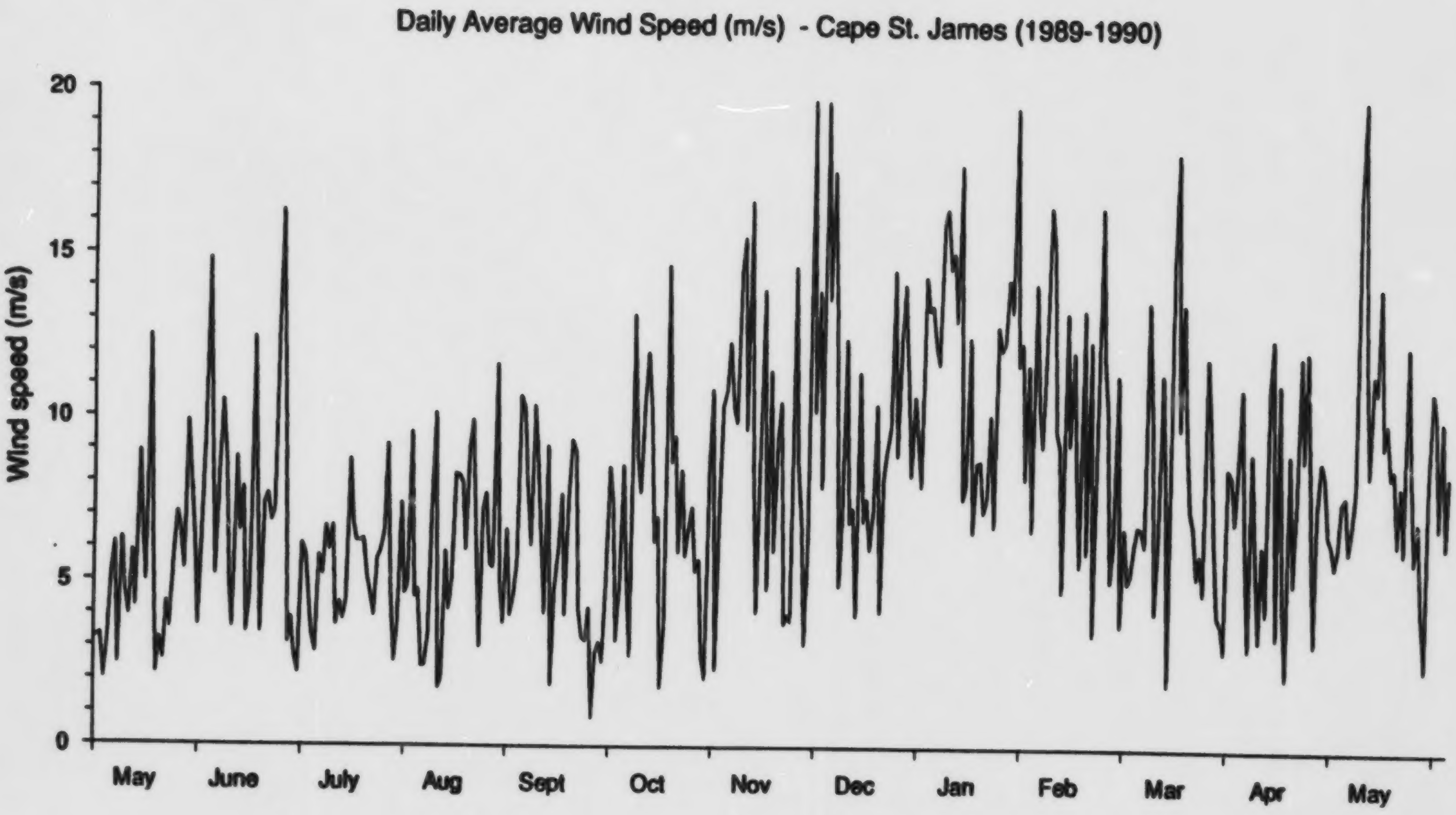
4.0 Wind Energy Resource

The most recently available archived wind data for one year were obtained from the Atmospheric Environment Service (May, 1989 - May 1990), as well as the corresponding temperature and pressure data, and were reformatted for use in the analysis. These data are presented in Figures 8 - 11. The temperature and pressure data were used to calculate the air density as per CSA guidelines (Figure 12)[2]. The air density values were used in the hindcast analysis to correct the power output of the wind turbine[3].

The 24 year averages for this site are shown in Figures 13 - 16[4]. The study year windspeeds are seen to be slightly lower than the long term average, however this means that the results of the analysis will not be 'best case' nor even 'average case' and therefore the results can be accepted with a fair degree of confidence of being conservatively representative.

The study year wind direction is different from the long term average, however wind direction will not have a significant effect on turbine output as the turbine would be located at a height well above the top of the island (see Section 5.0).

Temperatures and pressures during the study year are in the range of the long term average.



Daily Average Wind Speed (m/s) - Cape St. James (1989-1990)

Figure 8

Frequency Distribution of Wind Direction
Cape St. James (May, 1989-June, 1990)

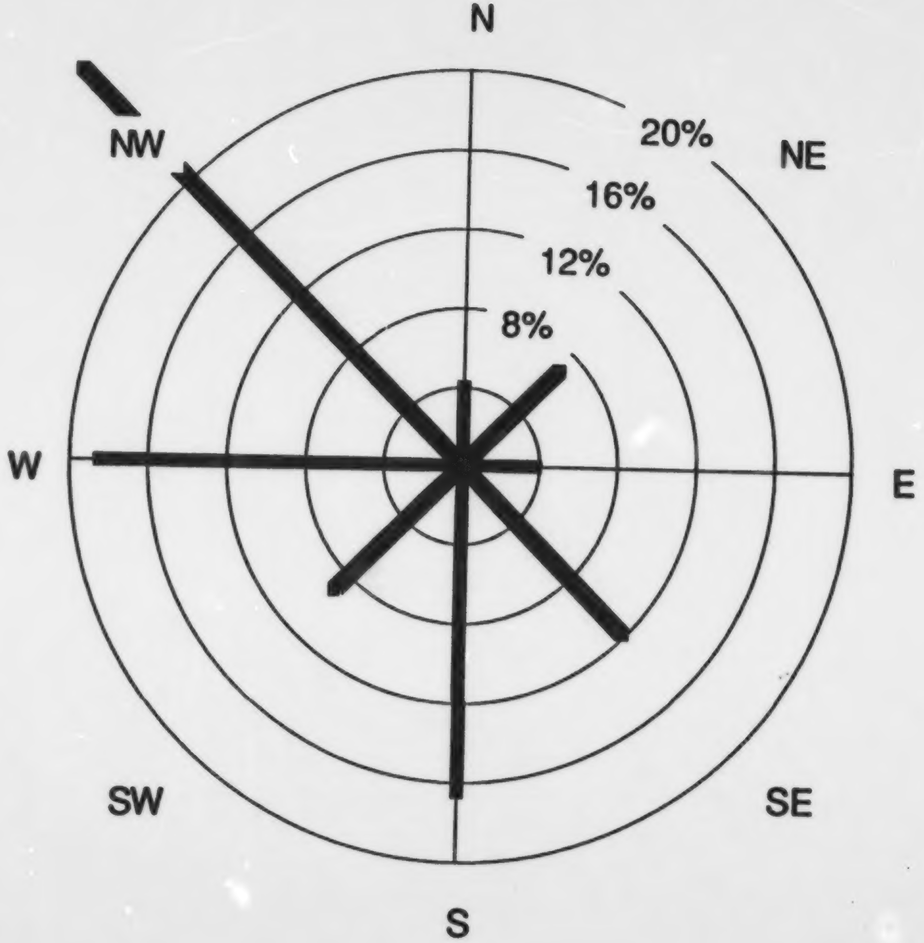


Figure 9

Daily Average Temperature (°C) - Cape St. James (1989-1990)

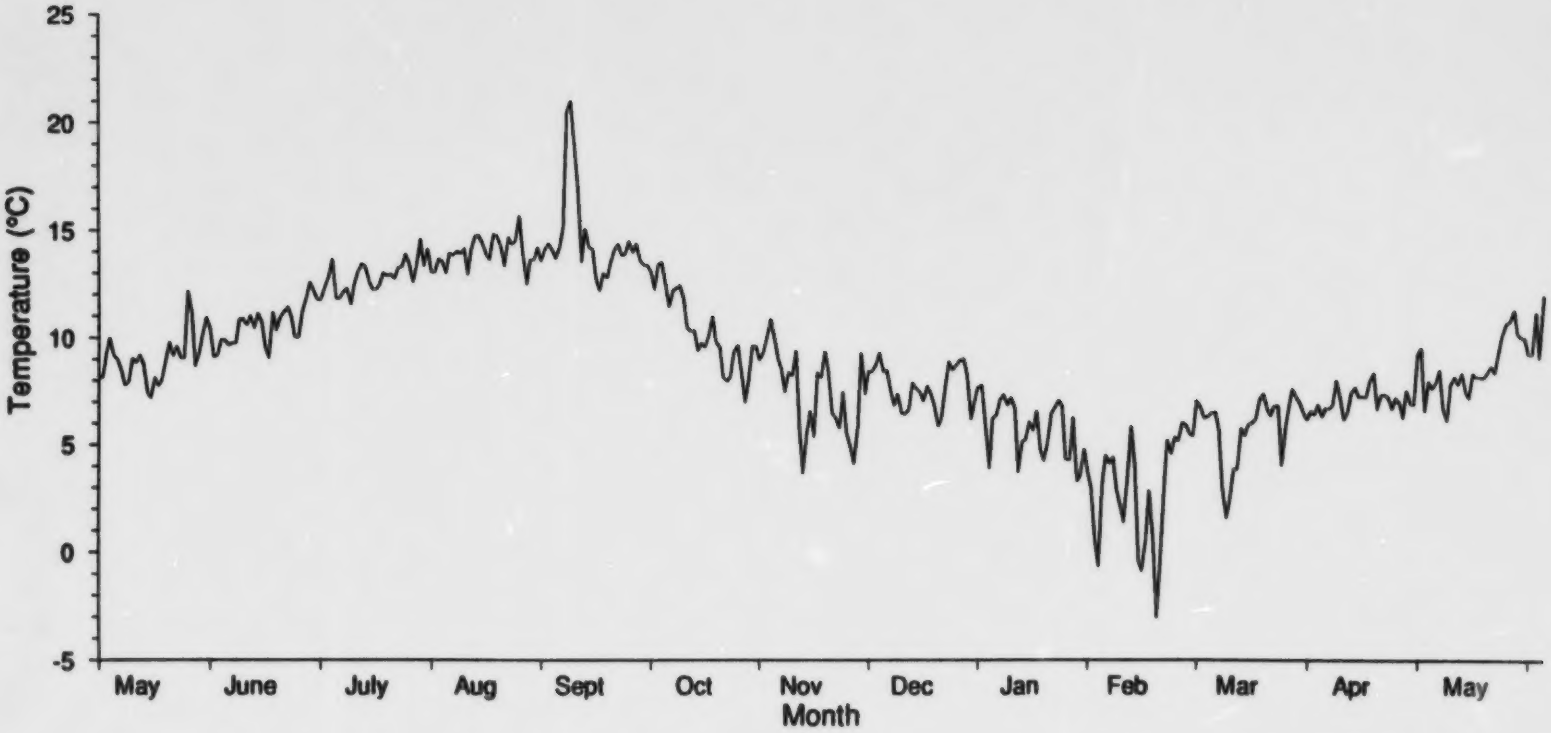


Figure 10

Daily Average Pressure (kPa) - Cape St. James (1989-1990)

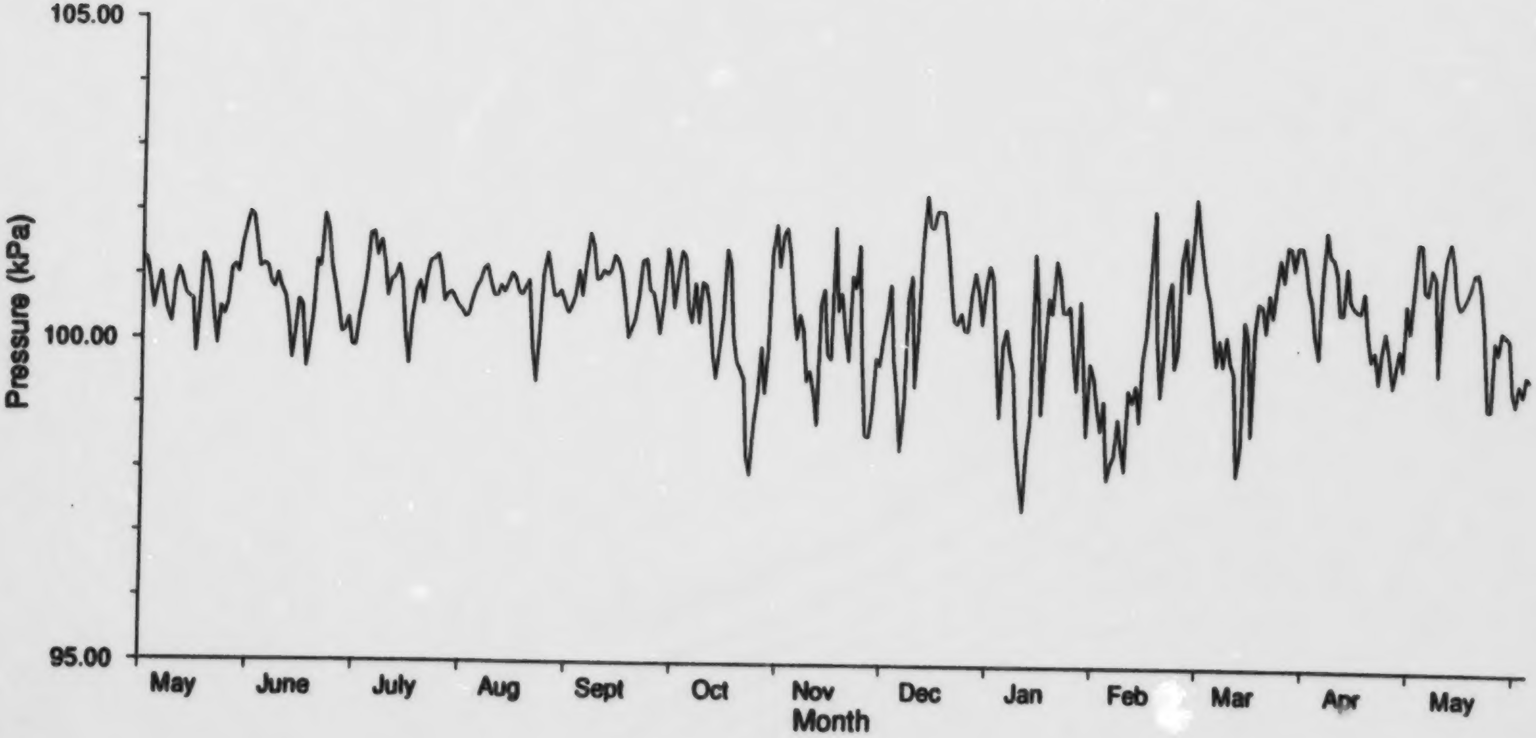


Figure 11

Daily Average Air Density (kg/cu. m) - Cape St. James (1989-1990)

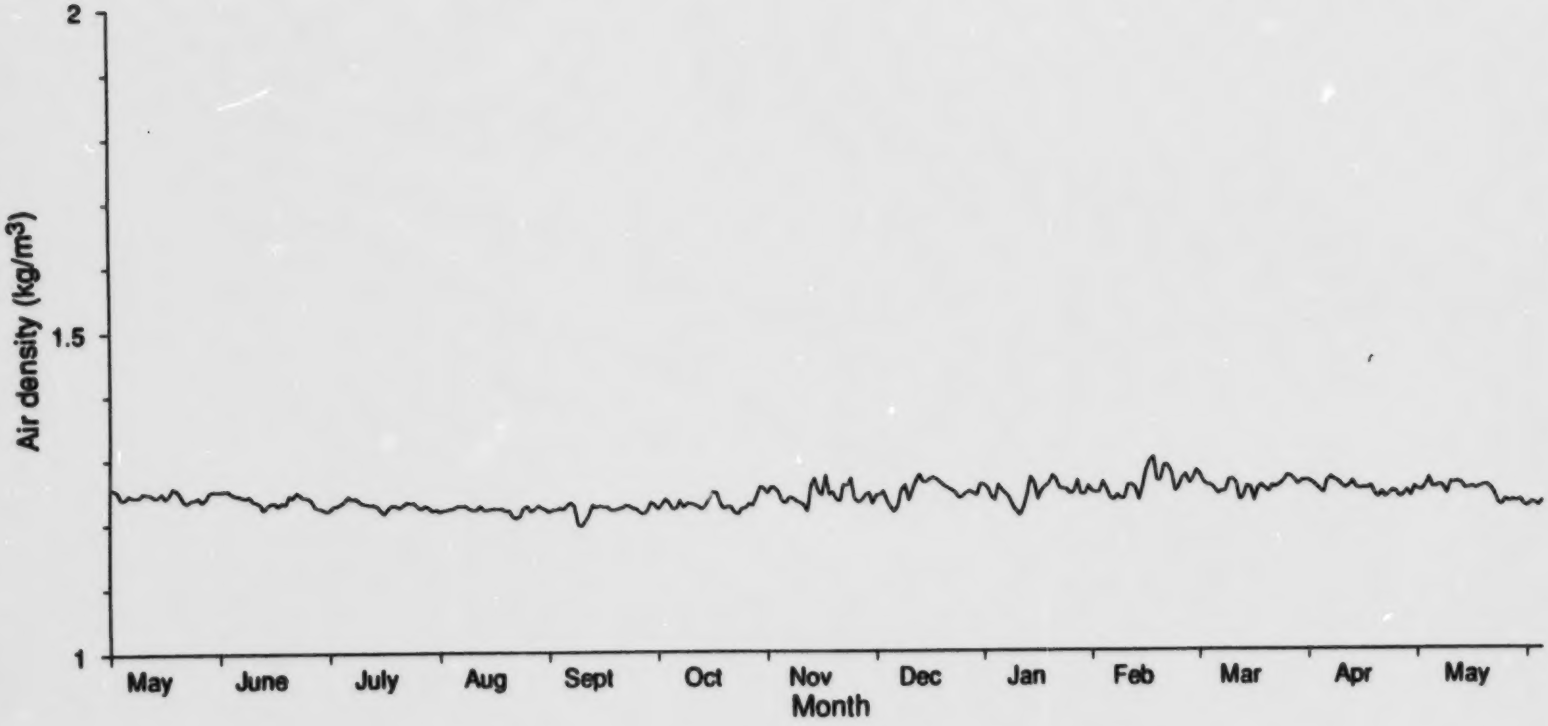


Figure 12

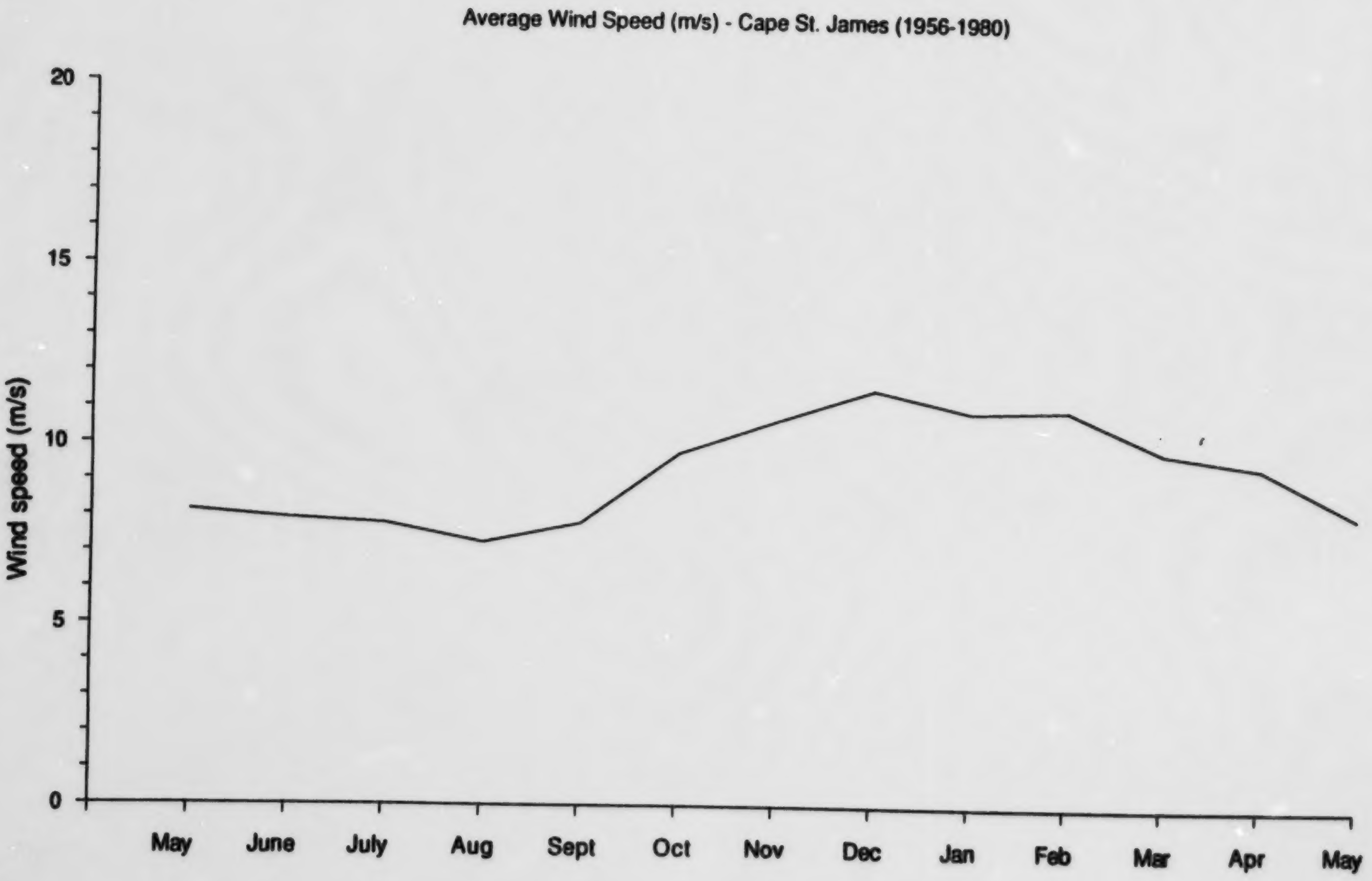

Average Wind Speed (m/s) - Cape St. James (1956-1980)
Wind speed (m/s)
20
15
10
5
0
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May

Figure 13

Frequency Distribution of Wind Direction
Cape St. James (1956 - 1980)

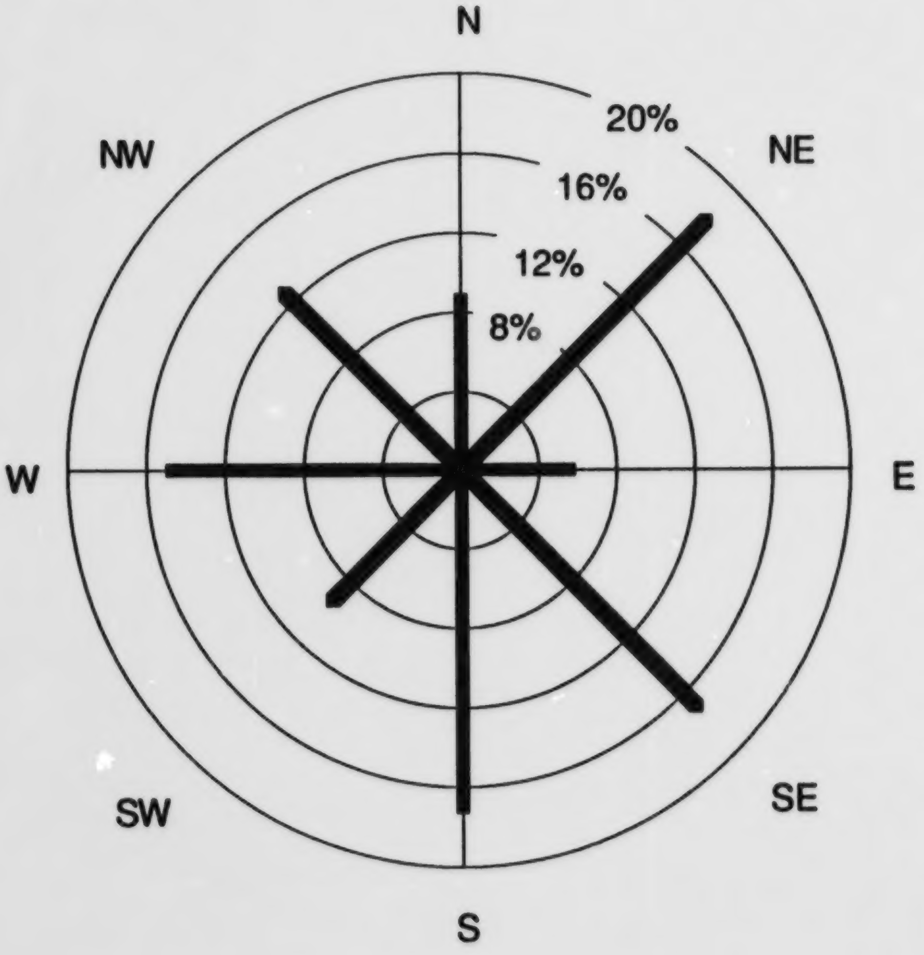


Figure 14

Average Temperature (°C) - Cape St. James (1956-1980)

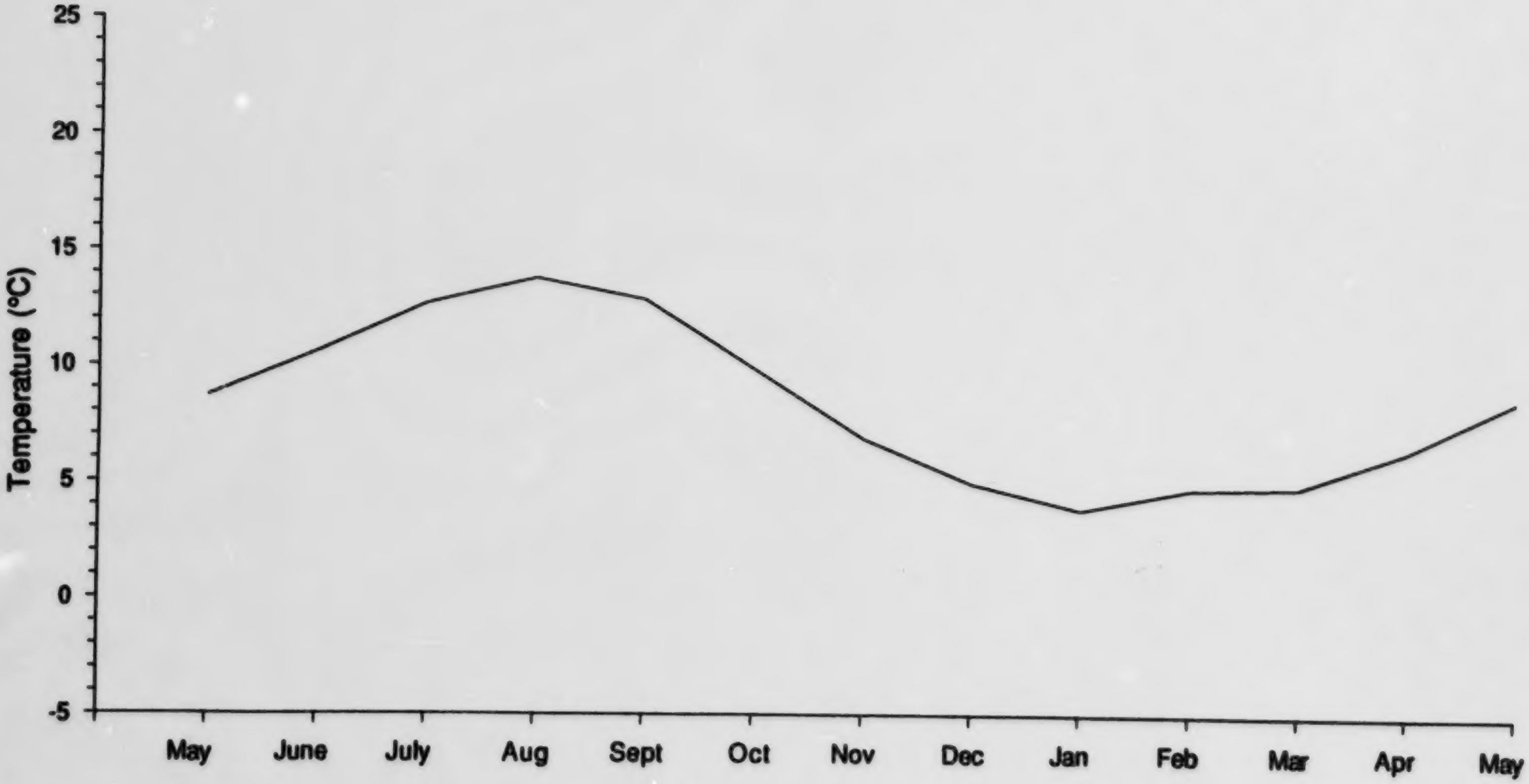


Figure 15

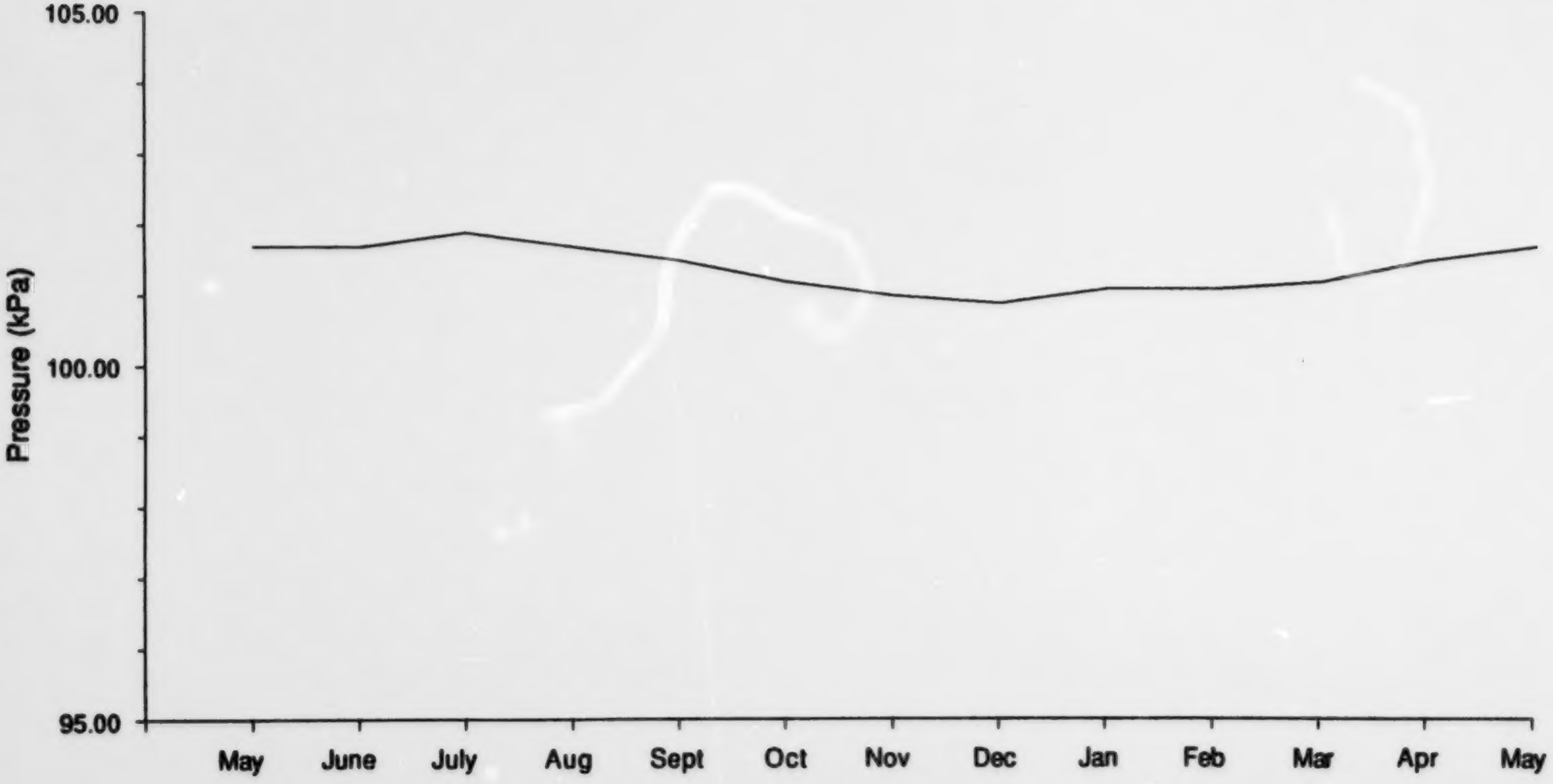

Average Pressure (kPa) - Cape St. James (1956-1980)

Figure 16

5.0 System design

During and after the site visit, Nor'wester undertook to perform a system design much as it would for a 'genuine client-purchase situation'. As this analysis is intended to be representative of remote sites elsewhere in Canada, it is critical that standard remote power application design processes and procedures are followed. Similarly, the specification of existing and appropriate equipment for this analysis is critical to the 'realness' of the results. For this reason, the wind turbine model chosen was the Bergey Windpower Co. Inc. Excel-R 10 kW model, which has a good operating history in remote sites, has been operated in Canada, and has a reputation for high reliability and low maintenance requirements; it is the largest commercially battery charging wind turbine currently available. The inverter/charger and control system chosen was, in fact, a major reason for conducting this study. The Advanced Energy Systems equipment, with its capability to synchronize the inverter output with a diesel system, was chosen as the only source of such equipment currently available.

Before visiting the site it was estimated that two Bergey Excel 10 kW turbines would be required to provide a significant portion of the loads as recorded at this site. However, it was quite obvious during the site reconnaissance that there is only sufficient space for one turbine and tower, therefore the design has been based on this constraint. The turbine and tower would probably be placed where the radio tower is now located.

The major components specified for the system are shown in Figure 17. The wind turbine is a Bergey Excel-R 10 kW unit on a 100 foot tilt-up tower for easy on site accessibility and maintenance. The 100' tower is required to place the turbine well above the surrounding topography (the island summit) and out of the majority of the turbulence. An electric winch would be required to raise and lower this tower. A spare set of blades is specified in anticipation of a rare major wind event exceeding the manufacturer's warranty wind speed of 120 mph, causing blade damage. The controller/inverter/charger would be an Advanced Energy Systems 3Ø 20 kW unit complete with engine controls, metering and switchgear.

The battery bank size is 77 kWh. This is based on trial runs of the hindcast analysis and the controller/inverter manufacturer's own simulation model. Table 2 shows the results of three hindcast runs for the month of October using a 77, 96 and 150 kWh battery bank. No fuel savings for larger battery banks are noted. A 77 kWh battery bank is the minimum size battery bank that will accept the charging rates possible from the wind turbine and the

Advanced Wind/Diesel Hybrid Major System Component Schematic

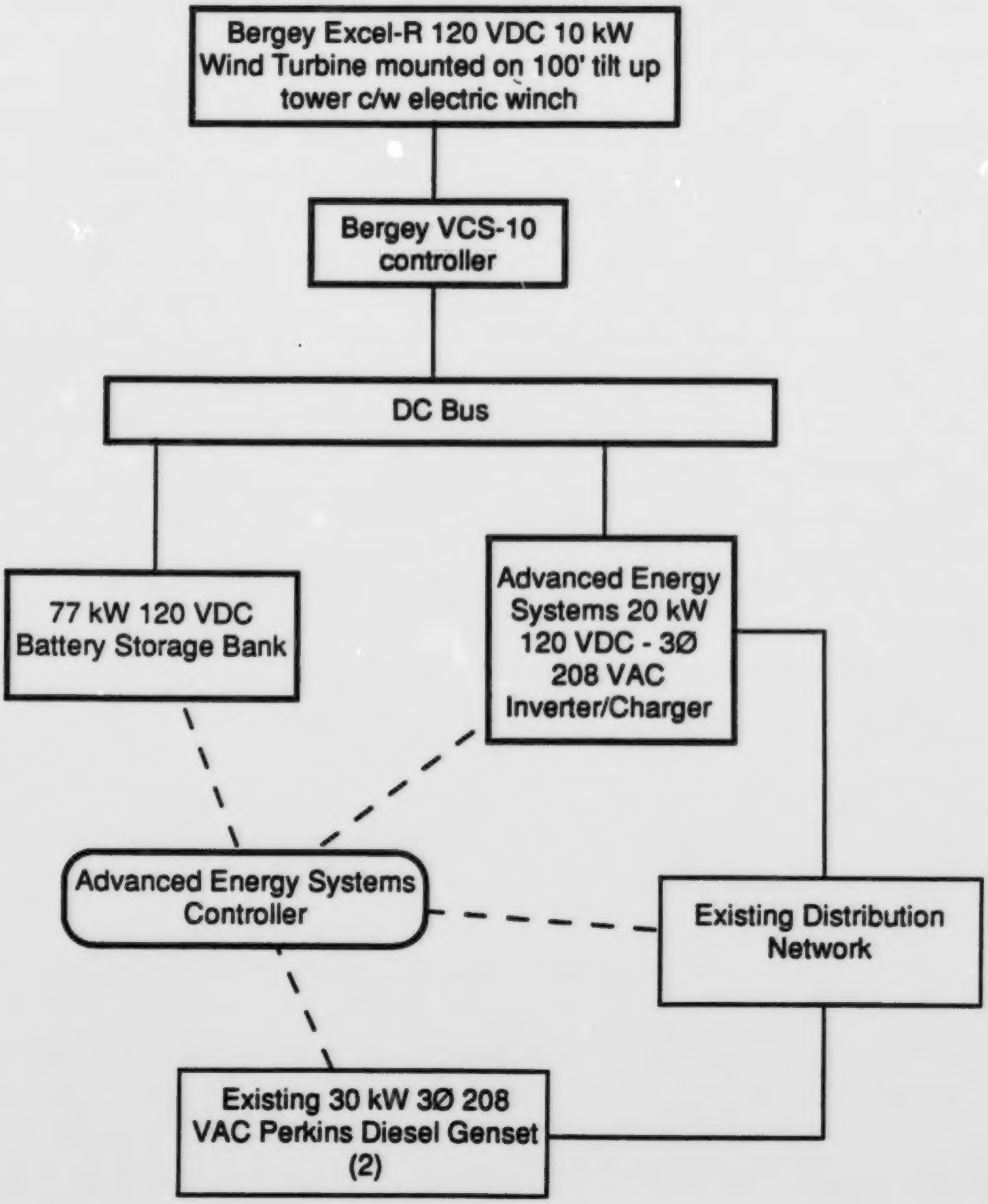

Bergey Excel-R 120 VDC 10 kW Wind Turbine mounted on 100' tilt up tower c/w electric winch
Bergey VCS-10 controller
DC Bus
77 kW 120 VDC Battery Storage Bank
Advanced Energy Systems 20 kW 120 VDC - 3Ø 208 VAC Inverter/Charger
Advanced Energy Systems Controller
Existing Distribution Network
Existing 30 kW 3Ø 208 VAC Perkins Diesel Genset (2)

Figure 17

Battery Size Comparison (based on month of October, 1989)

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
TOTALS				3647		2277	6257	5064	1431	2984	2369	1438	358

Battery capacity= 88.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
TOTALS				3647		2296	6257	5058	1412	2873	2375	1433	361

Battery capacity= 100.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
TOTALS				3647		2249	6257	5057	1312	2773	2382	1426	388

Table 2

charger/inverter. Larger battery banks do not result in correspondingly greater fuel savings as a result of the time required to recharge the batteries by the diesel, and a decrease in the utilization of the wind turbine (in other words with longer storage there exists more likelihood that the battery will not be able to accept the energy available from the turbine at any given instance).

If the site is automated the design would remain the same. The only change would be that the diesels would serve as a back up power source rather than a prime mover. To this end the 30 kW diesels would be replaced by 5 kW diesels to reduce fuel use when the diesel is required. It should be noted here that if the entire non-automated system (including the gensets) were to be replaced, the 30 kW diesels should be replaced by much smaller units (≈15 kW) in order to reduce fuel consumption and to allow the the inverter to handle short term peaks over the diesel capacity.

6.0 Budget costs

6.1 Capital Costs

6.1.1 Hybrid System

The following table (Table 3) outlines the budget costs for the complete installation of the advanced hybrid system for the Cape St. James site. It should be noted that the transportation and installation costs are high due to the difficulty of site access (helicopter or boat) and the remoteness of the site. This, however, would be representative of many of the remote sites elsewhere in Canada. These costs would be the same if the site is automated since the equipment that would be installed is identical.

Table 3
Capital Cost of Installed Hybrid System

Item	Cost
• Bergey Excel-R 10 kW wind turbine c/w VCS 10 controller	17,192.00
• spare set blades	3,500.00
• 100' tilt up tower	10,838.00
• tower raising kit c/w electric winch	4,000.00
• AES 20 kW Static Power Pack c/w switchgear	40,000.00
• battery storage bank	35,000.00
• transport to site	10,000.00
• tower installation	15,000.00
• turbine installation	10,000.00
• electrical installation	5,000.00
• travel, expenses	10,000.00
TOTAL	160,530.00

6.1.1 Present System

As the present system already exists, no capital costs are associated with this. However, if the site is automated it is assumed that the present diesel system would be removed and replaced with a much smaller unit (the salvage costs of the existing diesels is assumed to be insignificant). Table 4 outlines the expected costs associated with this replacement.

Table 4
Capital Cost to Replace Diesels for Automated Station

Item	Cost
• 2 5 kW diesel genset c/w heaters, controls, etc.	16,000.00
• transport	10,000.00
• removal of old units	8,000.00
• installation of new units	8,000.00
TOTAL	$42,000.00

6.2 Operation and Maintenance Costs

6.2.1 Hybrid System

The various components of the hybrid system with the exception of the diesels already on site require very little maintenance. The wind turbine has no scheduled maintenance and with only four moving parts and lifetime sealed bearings, no maintenance other than regular inspections are required. Normally the bearings require replacement after fifteen years. At the extremely energetic Cape St. James site this replacement may be required at ten years.

The tower itself requires no true maintenance, only regular inspections for tension and corrosion and perhaps the occasional adjustment of the guy wires would be necessary. The winch system would require regular lubrication.

The battery storage bank will require biannual service, which would involve topping up with distilled water and an equalization charge if indicated by sufficient disparity in cell specific gravities. It is expected that the batteries will need replacement after ten to fifteen years.

The controller and inverter require no maintenance whatsoever. It can be expected that over the life of the system some electronic components will require replacement.

The costs of maintaining the diesels are expected to be dramatically reduced with the installation of a hybrid system as the operating hours of the diesel will be greatly reduced. As well the diesel will normally be operating at approximately 90% of capacity rather than the present 30% or less. Operating under higher loads reduces carbon build up and other problems associated with operating diesel engines under low loads.

Table 5 summarizes the the expected operational and maintenance requirements and costs of the hybrid system. It is assumed that travel associated with these costs would be borne by the activities discussed under 6.2.1 (which have to be performed in any event), or be borne by the existing site staff.

Table 5
Hybrid System O&M Costs

Item	Annual Cost
• turbine and tower inspection and adjustment	0.00
• winch lubrication	25.00
• battery inspection and topping up	10.00
• electronics inspection, component replacement	100.00
TOTAL	135.00

Item	Rebuild cost
• battery replacement at year ten (1991$)	35,000.00
• turbine bearing replacement (1991$)	8,000.00
TOTAL	43,000.00

6.2.1 Present System

The existing diesel system requires regular servicing including lubrication and the replacement of filters, etc. In addition to this, the service history of the diesels indicates that repairs and adjustments are frequently required. If mechanical service is required beyond the capabilities of the meteorological technicians on site, it is very expensive to bring in service personnel. At present a return helicopter flight to the site costs $2700. Normally if repairs take more than a couple of hours two such flights would be required. Additional costs would include labour and replacement parts.

The estimated annual operation and maintenance costs are summarized in Table 6.

Table 6
Present System O&M Costs

Item	Annual Cost
• regular lubrication, oil and filter changes	500.00
• parts replacement	1000.00
• mechanical service, incl. labour and transport	28,000.00
TOTAL	$29,500.00

Item	Rebuild cost
• engine rebuild (year 6, 13, 20)	15,000.00
• generator rebuild (year 10)	8,000.00
TOTAL	23,000.00

7.0 Hindcast Analysis

7.1 General description of technique

'Hindcast' is a term coined to indicate the opposite of a forecast. Forecasts typically use an analysis of historical data to predict or generate future information, whereas hindcasts use historical data in conjunction with a 'what-if' situation to predict what would have happened. Hindcast analysis has the advantage of using real rather than artificially generated data. The results of such an analysis therefore are more realistic and can be more representative of the changes that would be effected with the 'what-if' situation occurring.

In the analysis developed for this study, past diesel and weather records are used in conjunction with the control strategy and operational characteristics of the hybrid system to generate a set of data that *would have resulted if* the hybrid system were installed at the beginning of the study year.

It was decided to use straightforward spreadsheet analysis techniques for the hindcast analysis. The use of a spreadsheet reduces programming time, allows easy user changes, error identification and simplifies graphical display of the analysis results. Lookup tables are used in place of complicated mathematical formulae and in turn allow easy modification or replacement when system components are changed or substituted.

7.2 Detailed description of the developed analysis tool

As the weather data is only available as hourly averages, and in order to keep the analysis relatively quick and simple as well as to reduce the volume of output, it was decided to perform the analysis on an hourly basis. The procedure used to perform the analysis based on the various inputs and the control strategy is given in flow chart form in Figure 18. Table 7 gives an example page of the output with the various headings used in the spreadsheet and a detailed description of how the data beneath each heading is derived follows:

Date - one line is created for each hour of the month from the entry of the first hour of the month on the first line.

Wind speed - this hourly data is directly placed into the spreadsheet from reformatted AES data for the site.

HINDCAST MODEL FLOW CHART

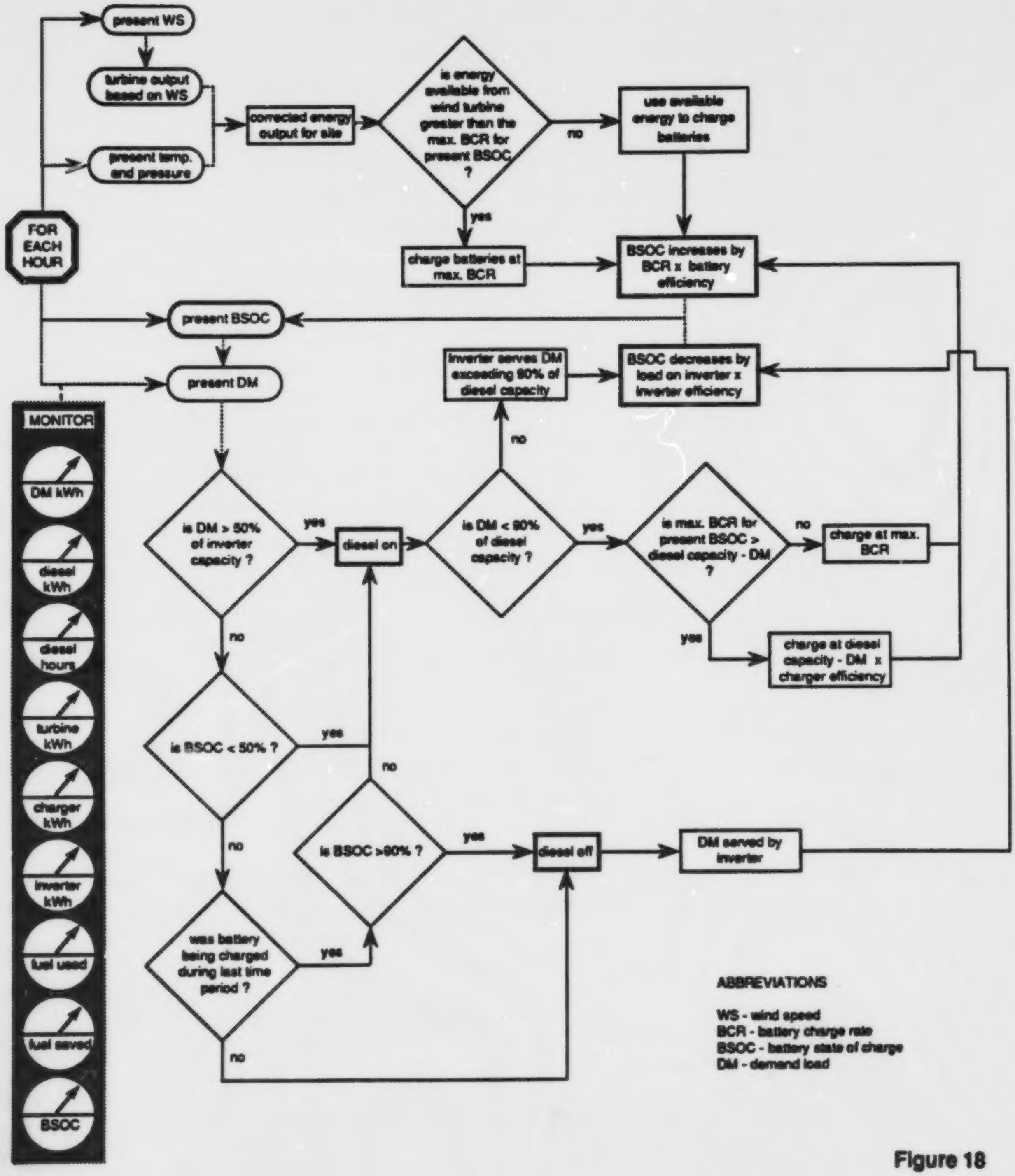

present WS
turbine output based on WS
present temp. and pressure
corrected energy output for site
is energy available from wind turbine greater than the max. BCR for present BSOC ?
no
use available energy to charge batteries
yes
charge batteries at max. BCR
BSOC increases by BCR x battery efficiency
FOR EACH HOUR
present BSOC
present DM
inverter serves DM exceeding 90% of diesel capacity
BSOC decreases by load on inverter x inverter efficiency
MONITOR
DM kWh
diesel kWh
diesel hours
turbine kWh
charger kWh
inverter kWh
fuel used
fuel saved
BSOC
no
is DM > 50% of inverter capacity ?
yes
diesel on
is DM < 90% of diesel capacity ?
yes
is max. BCR for present BSOC > diesel capacity - DM ?
no
charge at max. BCR
yes
charge at diesel capacity - DM x charger efficiency
no
is BSOC < 50% ?
yes
no
no
is BSOC >90% ?
yes
diesel off
DM served by inverter
was battery being charged during last time period ?
yes
no
ABBREVIATIONS
WS - wind speed
BCR - battery charge rate
BSOC - battery state of charge
DM - demand load

Figure 18

Table 7

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
1-Nov-89 00:00	6.7	2.922	1.253	2.988	41	2.988	10	0.000	0.000	9.597	0.0	5.5	0
1-Nov-89 01:00	7.2	3.574	1.252	3.652	33	3.652	9	22.563	12.000	0.000	9.0	-3.7	1
1-Nov-89 02:00	6.7	2.922	1.252	2.985	47	2.985	9	22.689	12.000	0.000	9.1	-3.7	1
1-Nov-89 03:00	7.2	3.574	1.251	3.650	59	3.650	9	13.550	3.975	0.000	6.4	-1.1	1
1-Nov-89 04:00	8.6	5.222	1.251	5.334	66	1.732	9	11.027	1.732	0.000	5.8	-0.5	1
1-Nov-89 05:00	9.2	5.825	1.252	5.954	69	1.135	9	10.873	1.135	0.000	5.7	-0.4	1
1-Nov-89 06:00	10.3	7.312	1.251	7.469	71	0.861	8	0.000	0.000	8.065	0.0	5.2	0
1-Nov-89 07:00	9.7	6.594	1.250	6.730	62	2.565	8	0.000	0.000	7.791	0.0	5.1	0
1-Nov-89 08:00	9.7	6.594	1.250	6.730	56	5.325	8	0.000	0.000	8.190	0.0	5.2	0
1-Nov-89 09:00	10.8	8.277	1.251	8.452	52	8.090	8	0.000	0.000	8.421	0.0	5.2	0
1-Nov-89 10:00	10.8	8.277	1.251	8.452	49	8.452	8	0.000	0.000	8.001	0.0	5.1	0
1-Nov-89 11:00	10.8	8.277	1.250	8.443	48	8.443	10	0.000	0.000	9.597	0.0	5.5	0
1-Nov-89 12:00	10.8	8.277	1.250	8.449	44	8.449	8	0.000	0.000	8.295	0.0	5.2	0
1-Nov-89 13:00	10.8	8.277	1.249	8.440	43	8.440	8	0.000	0.000	7.707	0.0	5.1	0
1-Nov-89 14:00	9.7	6.594	1.247	6.715	41	6.715	8	0.000	0.000	8.190	0.0	5.2	0
1-Nov-89 15:00	10.3	7.312	1.247	7.444	38	7.444	8	21.534	12.000	0.000	8.7	-3.5	1
1-Nov-89 16:00	11.4	9.090	1.246	9.248	55	6.170	9	16.295	6.170	0.000	7.1	-1.6	1
1-Nov-89 17:00	10.3	7.312	1.247	7.441	65	1.913	9	11.324	1.913	0.000	5.8	-0.6	1
1-Nov-89 18:00	10.8	8.277	1.245	8.415	68	1.272	9	10.549	1.272	0.000	5.7	-0.4	1
1-Nov-89 19:00	11.4	9.090	1.245	9.239	70	0.861	10	0.000	0.000	9.744	0.0	5.5	0
1-Nov-89 20:00	13.3	10.000	1.244	10.153	61	3.373	10	0.000	0.000	9.912	0.0	5.5	0
1-Nov-89 21:00	15.0	9.700	1.242	9.835	53	7.318	9	0.000	0.000	8.862	0.0	5.3	0
1-Nov-89 22:00	15.0	9.700	1.241	9.829	49	9.829	8	0.000	0.000	8.358	0.0	5.2	0
1-Nov-89 23:00	14.4	9.950	1.239	10.073	48	10.073	10	0.000	0.000	9.933	0.0	5.5	0
2-Nov-89 00:00	14.4	9.950	1.238	10.064	46	10.064	10	0.000	0.000	9.597	0.0	5.5	0
2-Nov-89 01:00	12.8	10.000	1.237	10.101	44	10.101	9	0.000	0.000	9.093	0.0	5.4	0
2-Nov-89 02:00	13.3	10.000	1.237	10.101	43	10.101	9	0.000	0.000	9.219	0.0	5.4	0
2-Nov-89 03:00	12.8	10.000	1.237	10.098	41	10.098	9	0.000	0.000	8.883	0.0	5.3	0
2-Nov-89 04:00	11.9	9.829	1.237	9.925	40	9.925	9	0.000	0.000	8.610	0.0	5.3	0
2-Nov-89 05:00	11.4	9.090	1.236	9.173	39	9.173	9	0.000	0.000	9.156	0.0	5.4	0
2-Nov-89 06:00	10.8	8.277	1.234	8.341	37	8.341	8	21.555	12.000	0.000	8.7	-3.5	1
2-Nov-89 07:00	11.4	9.090	1.234	9.161	54	6.170	8	14.594	6.170	0.000	6.6	-1.5	1
2-Nov-89 08:00	10.8	8.277	1.234	8.341	65	2.112	8	11.010	2.112	0.000	5.8	-0.6	1
2-Nov-89 09:00	9.7	6.594	1.235	6.649	68	1.272	8	10.318	1.272	0.000	5.6	-0.4	1
2-Nov-89 10:00	10.3	7.312	1.235	7.374	70	0.861	8	0.000	0.000	8.001	0.0	5.1	0
2-Nov-89 11:00	10.8	8.277	1.236	8.349	62	2.819	10	0.000	0.000	9.597	0.0	5.5	0
2-Nov-89 12:00	9.7	6.594	1.236	6.653	54	6.170	8	0.000	0.000	8.295	0.0	5.2	0

Potential turbine output (@ std temp & press) - the value corresponding to the *Wind speed* is obtained from a lookup table, based on manufacturer's published power curve.

Air density - this value is calculated from AES temperature and pressure data and directly placed in the spreadsheet.

Potential turbine output at site - the *Air density* is used to correct the *turbine output at standard temperature and pressure* to the actual potential output under the site conditions.

BSOC - the battery state of charge is determined by adding the *Actual turbine output* (multiplied by the battery efficiency) and the *Inverter charging load* (multiplied by the battery efficiency) to the previous hours *BSOC*. If the inverter is operating, the *Inverter demand load* (multiplied by the inverter efficiency at that load) is subtracted from the previous *BSOC*.

Actual turbine output - if the *Potential turbine output* is less than the charge rate that can be accepted by the batteries at the present *BSOC*, then this is equal to the *Potential turbine output*.. Otherwise this is equal to the charge rate that can be accepted by the batteries.

Demand - this is equal to the daily load for that day multiplied by the load factor for that hour.

Diesel load - if the diesel is off (*Diesel hours*=0) this is zero, otherwise it is the *Demand* plus the *Inverter charging load* (multiplied by the charger efficiency at that load) as long as this does not exceed 90% of the diesel capacity, if it does this is equal to the diesel capacity.

Inverter charging load - if the diesel is off (*Diesel hours*=0) this is zero, otherwise if the charge rate for the present *BSOC* (multiplied by the charger efficiency) plus the *Demand* is less than 90% of the diesel capacity it will equal the charge rate, if this is greater than 90% it will equal 90% of the diesel capacity minus the *Demand* (but will not be less than zero).

Inverter demand load - if the diesel is on (*Diesel hours*=1) and the *Demand* is less than or equal to 90% of the diesel capacity this will be zero, if the diesel is on and the *Demand* is greater than 90% of the diesel capacity then it will equal the *Demand* minus 90% of the diesel capacity. If the diesel is off (*Diesel hours*=0) it will equal the *Demand*.

Fuel used - if the diesel is on (*Diesel hours*=1) then this will equal the *Diesel load* multiplied by the fuel use formula, otherwise this is equal to zero.

Fuel saved - this equals the *Demand* multiplied by the fuel use formula minus the *Fuel used* (negative values indicate that extra fuel is being used to charge the batteries).

Diesel hours - if the *BSOC* is less than 50%, or if the *Demand* is greater than 50% of the inverter capacity, or if the *BSOC* is less than 90% of the battery capacity and the *inverter charging load* was greater than zero in the previous hour this will equal 1, otherwise it will equal zero.

7.3 Inputs

The weather data is imported as hourly averages from the data supplied by AES. A spreadsheet listing of the data was prepared and the air density was calculated in this spreadsheet. Thus only the wind speed and air density were required to be imported into the analysis tool.

The actual daily loads were imported from a spreadsheet listing of the study year actual data obtained from the site records. The hourly values were then generated from these using the load factors determined through the method described in Section 3.2.

The turbine output was determined from the power curve supplied by the manufacturer (Figure 19). A lookup table was used to determine output for any particular windspeed. This lookup table can be replaced with data for any wind turbine. Similarly, the charge rate of the turbine controller for various battery states of charge was provided by the manufacturer (Figure 20) and a lookup table was created. Outputs and efficiencies of the inverter/charger at various battery states of charge and rates were also obtained from the manufacturer and put into lookup tables. Again these tables can be easily modified for different inverter/charger sizes.

The fuel consumption rate of the diesels at various loads was obtained from the manufacturer; since this is a simple curve a formula was used in the spreadsheet to determine fuel use (Figure 21). This is an idealized curve, it is expected that in practice the curve would be much more non-linear (greater inefficiency at low loads). Fuel records do exist for the site, but these are highly inaccurate as they are taken from dip readings of a

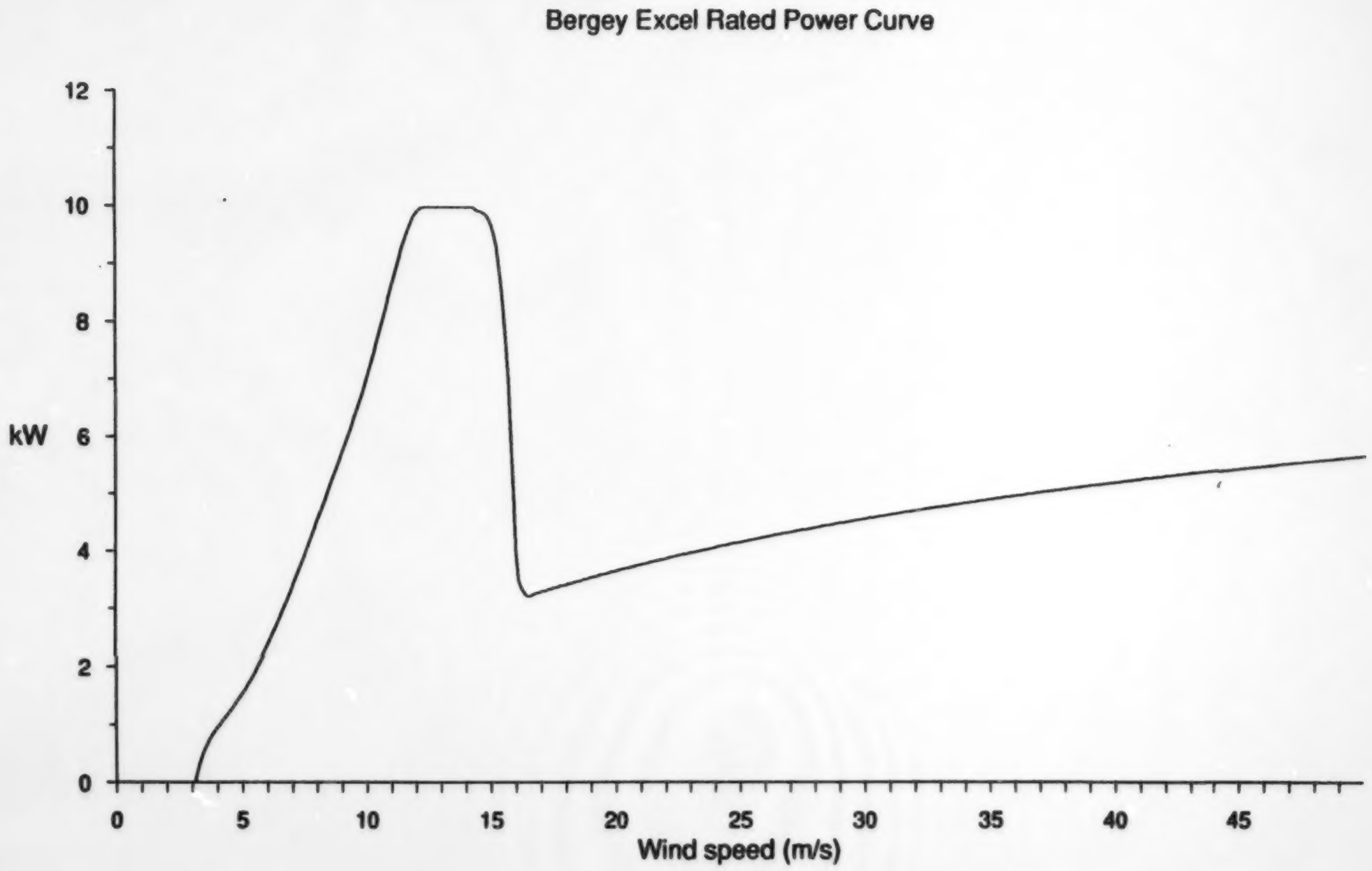

Bergey Excel Rated Power Curve

Figure 19

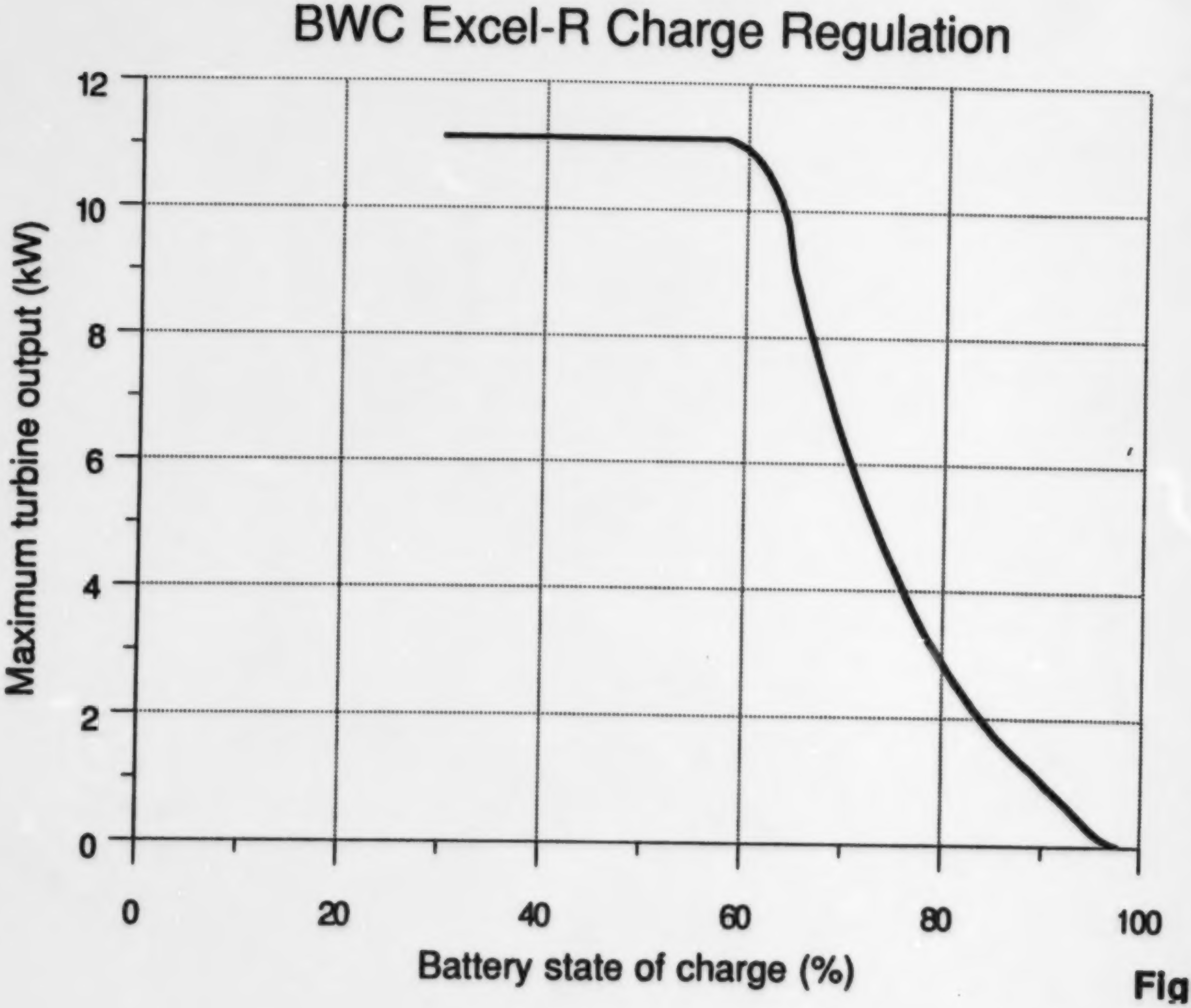

BWC Excel-R Charge Regulation
Maximum turbine output (kW)
0
2
4
6
8
10
12
Battery state of charge (%)
0
20
40
60
80
100

Figure 20

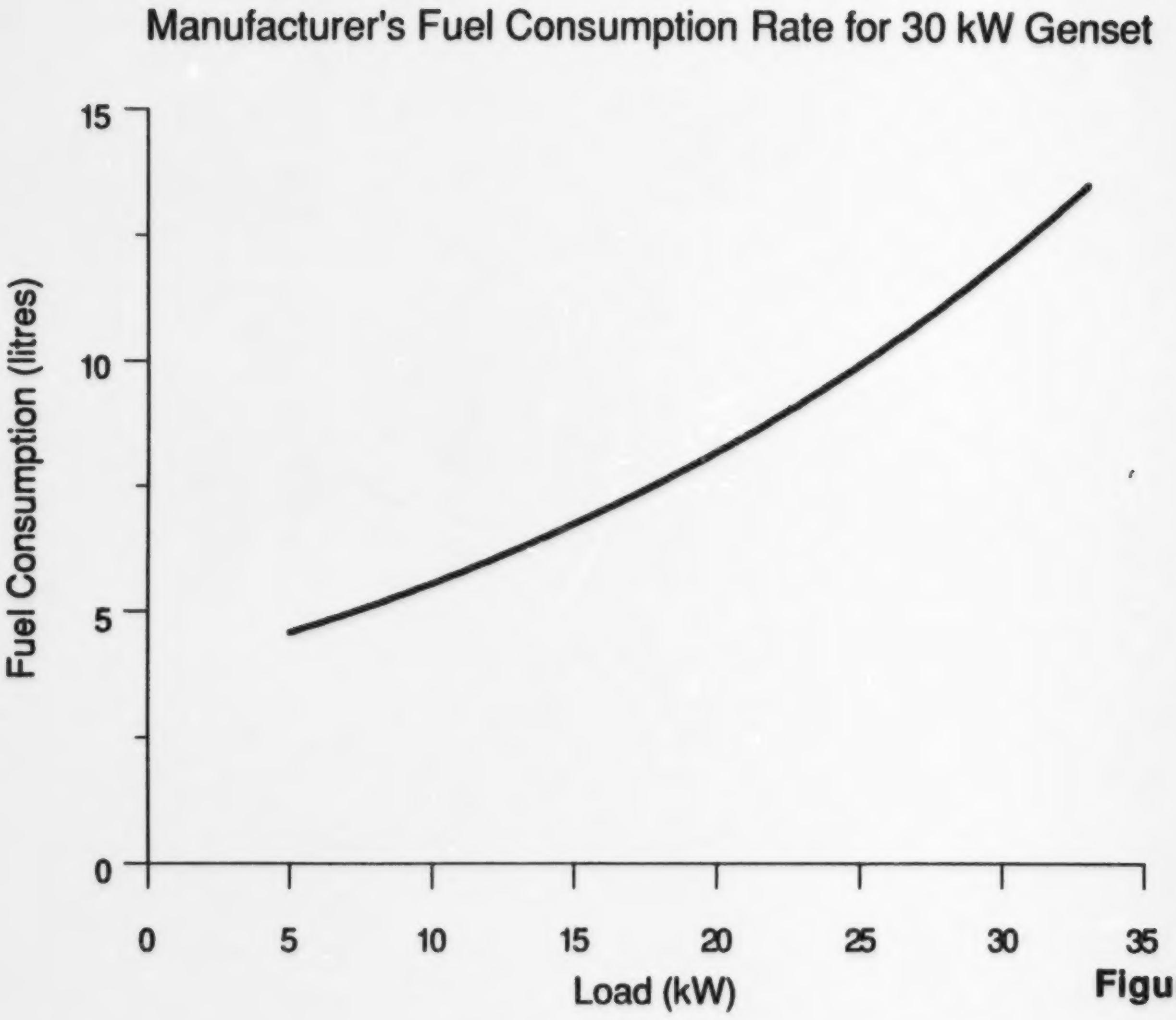

Manufacturer's Fuel Consumption Rate for 30 kW Genset
Fuel Consumption (litres)
15
10
5
0
0
5
10
15
20
25
30
35
Load (kW)

Figure 21

cylindrical tank on its side. As a result, a slight change in angle of the dip stick yields large differences in volume[5]. These records were rejected for use in this work.

7.4 Sources of inaccuracies

There are several sources of inaccuracy in the hindcast analysis tool developed, however none of these are deemed to be overly significant. Using hourly data and hourly updates is the single greatest source of inaccuracy. This procedure ignores instantaneous changes in demand and wind speed. However, the data is not available on a shorter time base and the tool would become overly large, cumbersome and slow at shorter time periods. The use of existing formulae to simulate short term changes would also detract from the 'reality' of the hindcast method. It is also expected that any fluctuations over the hour would generally be averaged out over the course of an hour and the total results for a month would average out these effects even further.

The battery state of charge using this method can go below the 50% and 90% limits set in the control strategy hourly method. In other words there will be time delays of less than an hour in stopping or starting the battery charging. This may have an effect for several hours when these limits are exceeded; it probably has little significance over the long term analysis period.

The hourly load data generated from daily consumption and hourly load factors derived from a typical day (see Section 3.2) provide another source of inaccuracy. Although this may effect any one given hour or one day's pattern; this probably has negligible significance over the analysis period.

The efficiency at which a battery accepts a charge has been arbitrarily set at 85%. In reality this efficiency is affected by a number of factors such as battery state of charge, battery condition, the charge rate, and battery temperature as well as others. It is impossible to include all these factors in an analysis tool of this scope. Again over the long term this inaccuracy is probably averaged out and in any event should present a worst case figure.

8.0 Results

The hindcast analysis tool was run a month at a time for three situations. The first run used the actual recorded loads. A subsequent run was made assuming that the loads could be reduced to 60% of the present loads. The third run assumed that the site was automated. An example of the output from the hindcast analysis for the month of November using actual loads is given in Appendix B. The graphical results for the entire study year are provided in Appendix C.

Figures 22 to 25 graphically present the results for November based on the actual loads. Figure 22 and 23 illustrate the relative contributions of the wind turbine and the diesel powered inverter/charger to the battery state of charge. The effect of the wind turbine is seen to slow the discharge of the batteries. In Figures 24 and 25 the relative contributions of the battery operated inverter and the diesel to demand supply are illustrated. Frequent operation of the diesel is seen, mostly as a result of the demand exceeding 50% of the inverter capacity at which time the diesel is turned on (in reality the this limit would be adjusted upward to reduce engine starts). The net result is a 37% savings in fuel consumption for this month.

Figures 26 to 29 present the results for November based on an assumed load of 60% of the actual load. From the figures a drastic reduction in diesel operation is noted. A fuel savings of 72% results from this load reduction. In fact it is more realistic to compare the fuel used in the reduced load scenario to the fuel used in the full load situation without the hybrid system. It is possible to make these load reductions with the hybrid system installed, however without the hybrid system the diesel must be kept loaded at least to its present level. A fuel savings of over 75% is made during this month if the full load situation without the hybrid system is compared to the 60% load situation with the hybrid system.

The graphical results of the analysis, assuming site automation, for the 'worst case' and the 'best case' months are provided at the end of Appendix C. The analysis results for November assuming the site is automated indicate a 92% fuel savings.

Tables 8 summarizes the results of the analysis for the study year. Annual fuel savings with the hybrid system and reduced loads are over 65%. The automated station using a hybrid system yields an annual fuel savings of over 88%. Figure 30 graphically illustrates

based on actual loads

Hindcast Battery Charging History (1. Nov - 15. Nov)

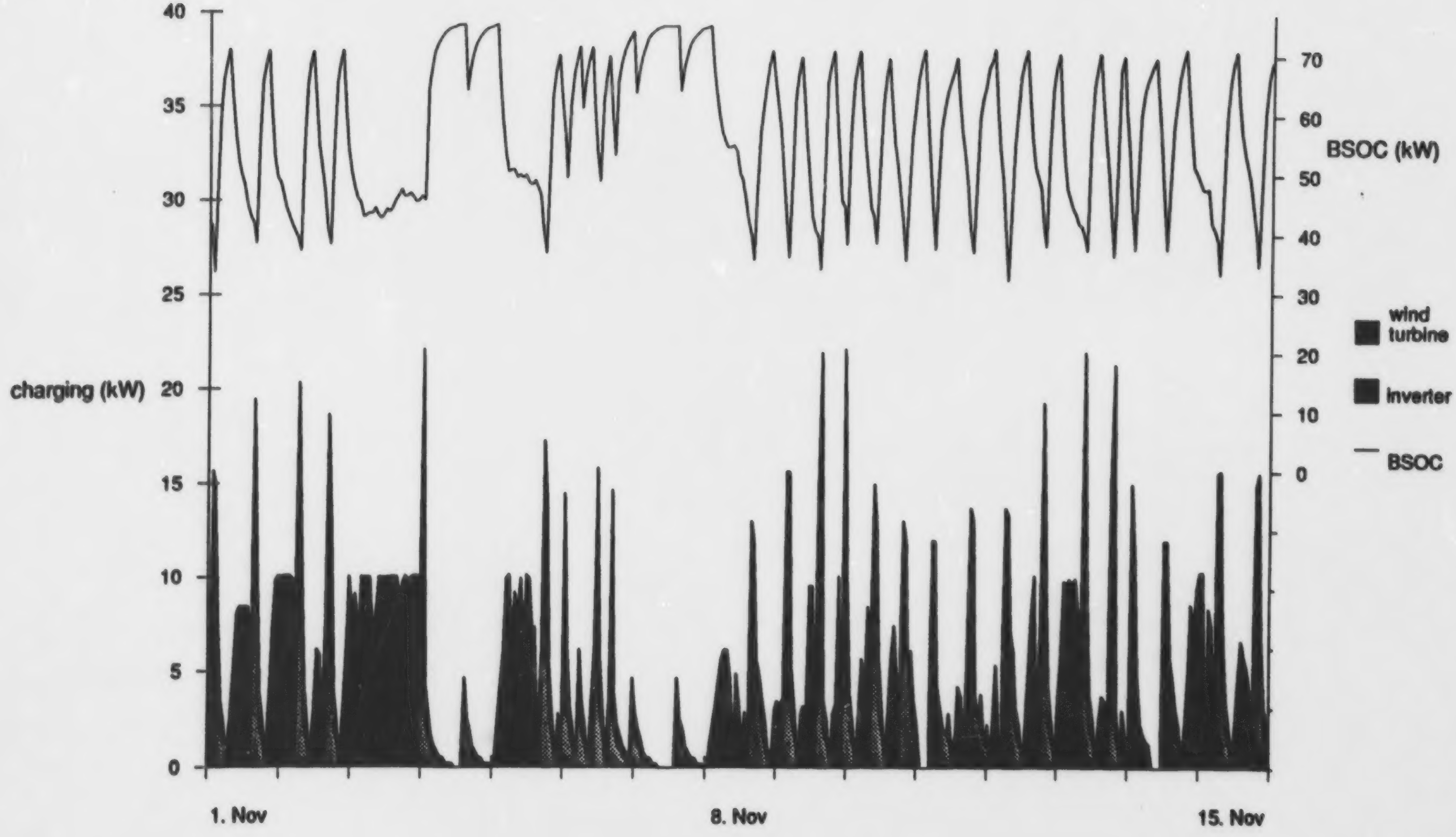


Figure 22

based on actual loads

Hindcast Battery Charging History (16. Nov - 30. Nov)

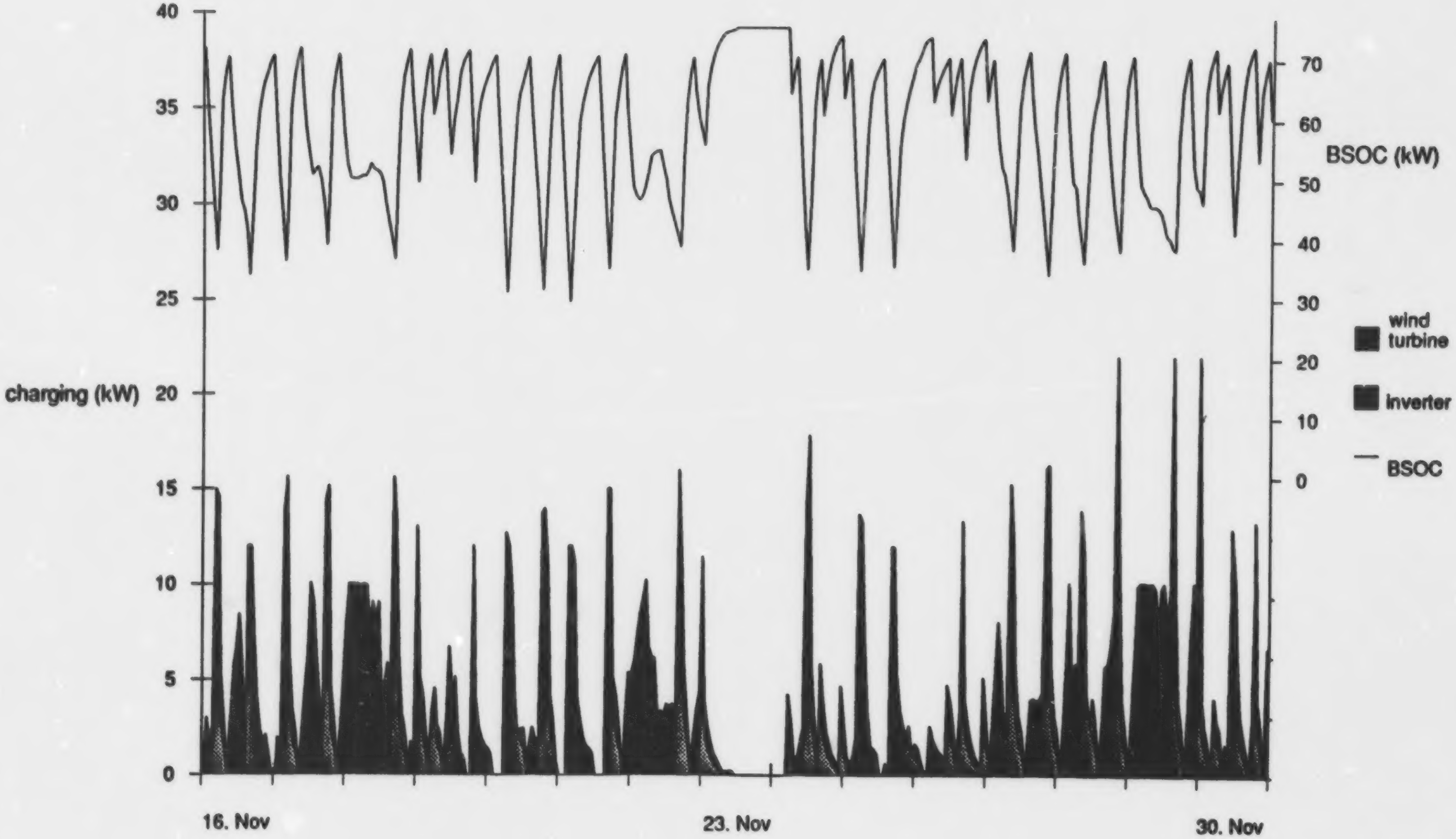


Figure 23

based on actual loads

Hindcast Load History (1. Nov - 15. Nov)

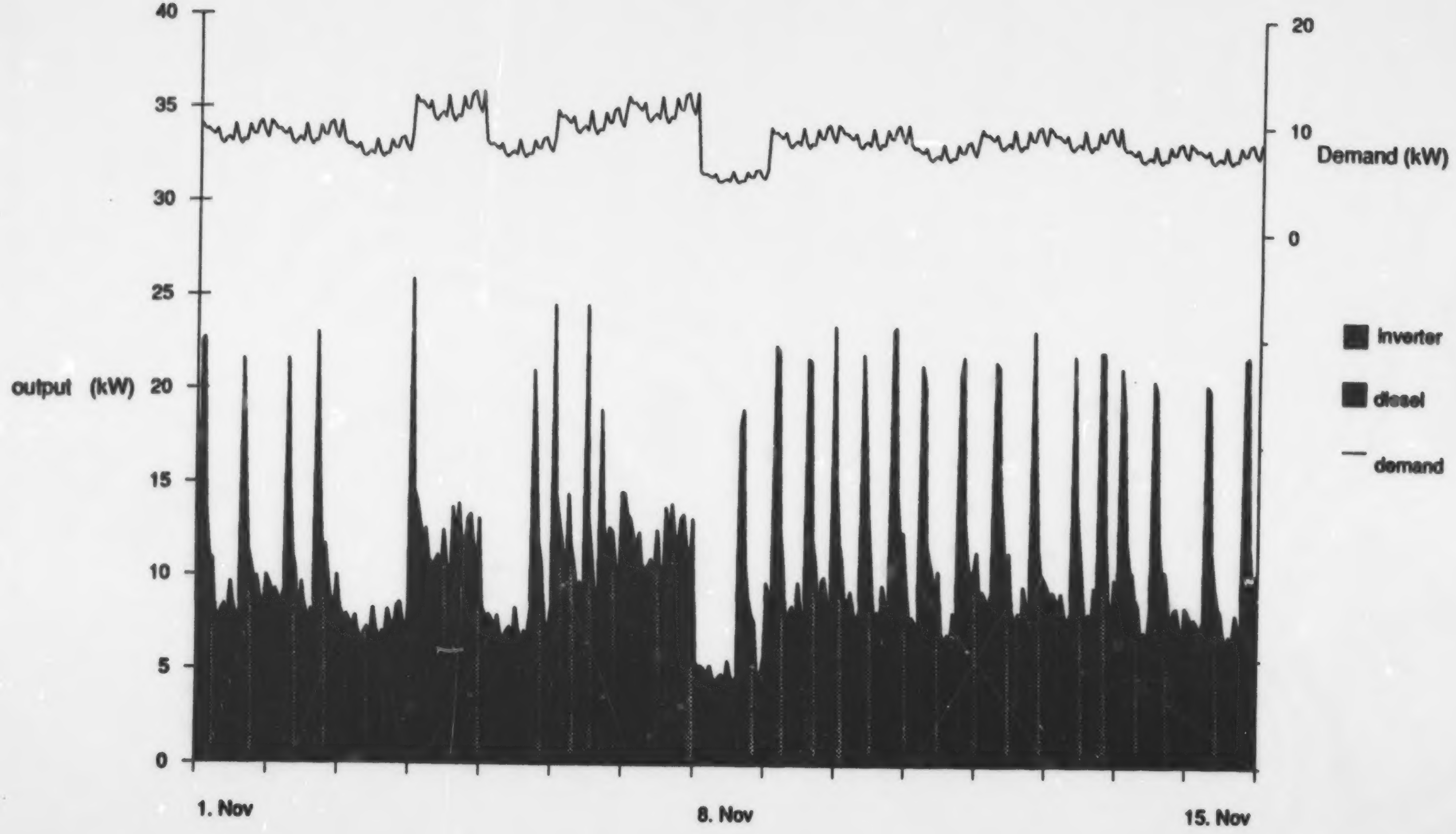


Figure 24

based on actual loads

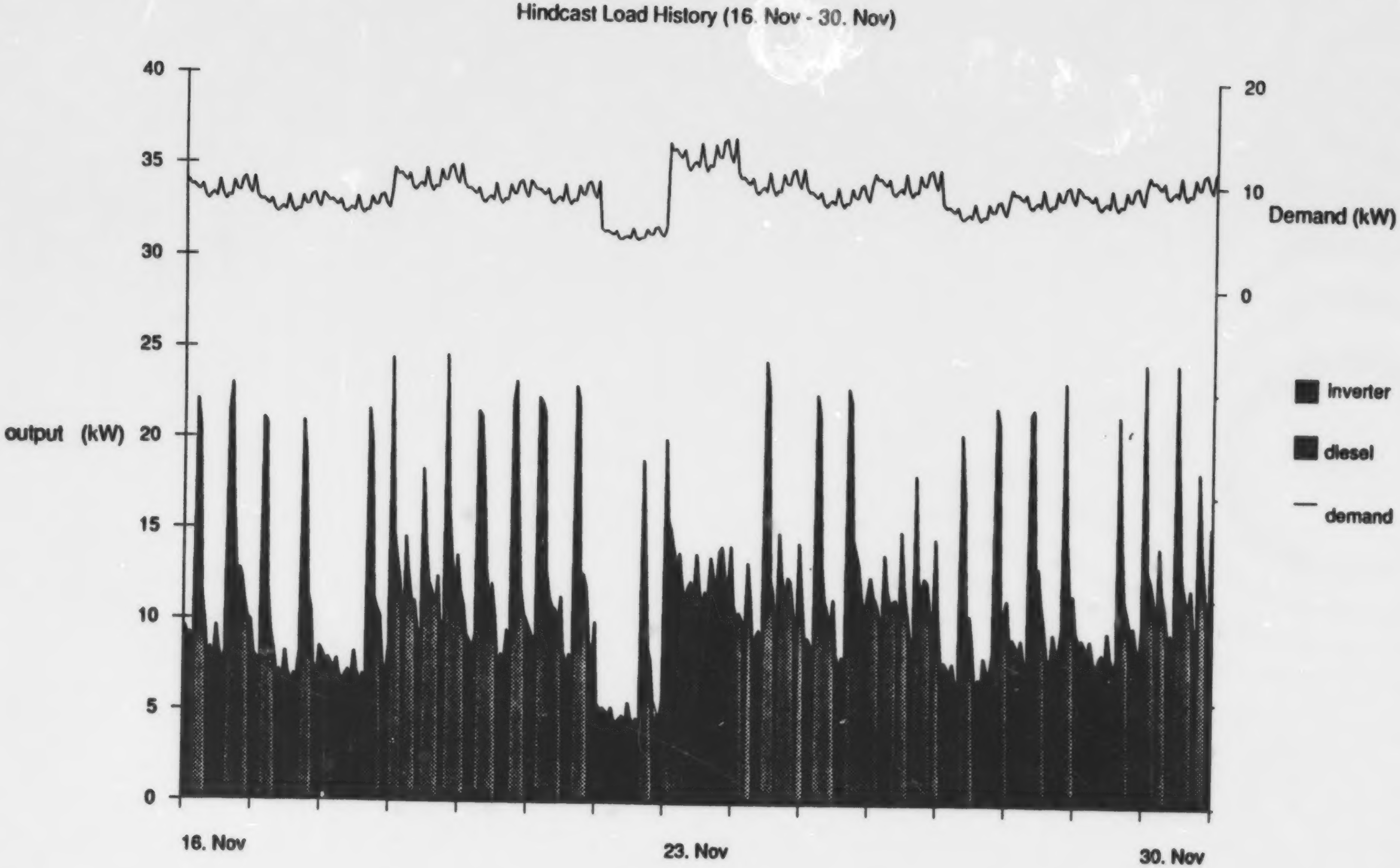


Figure 25

based on 60% of actual loads

Hindcast Battery Charging History (1. Nov - 15. Nov)

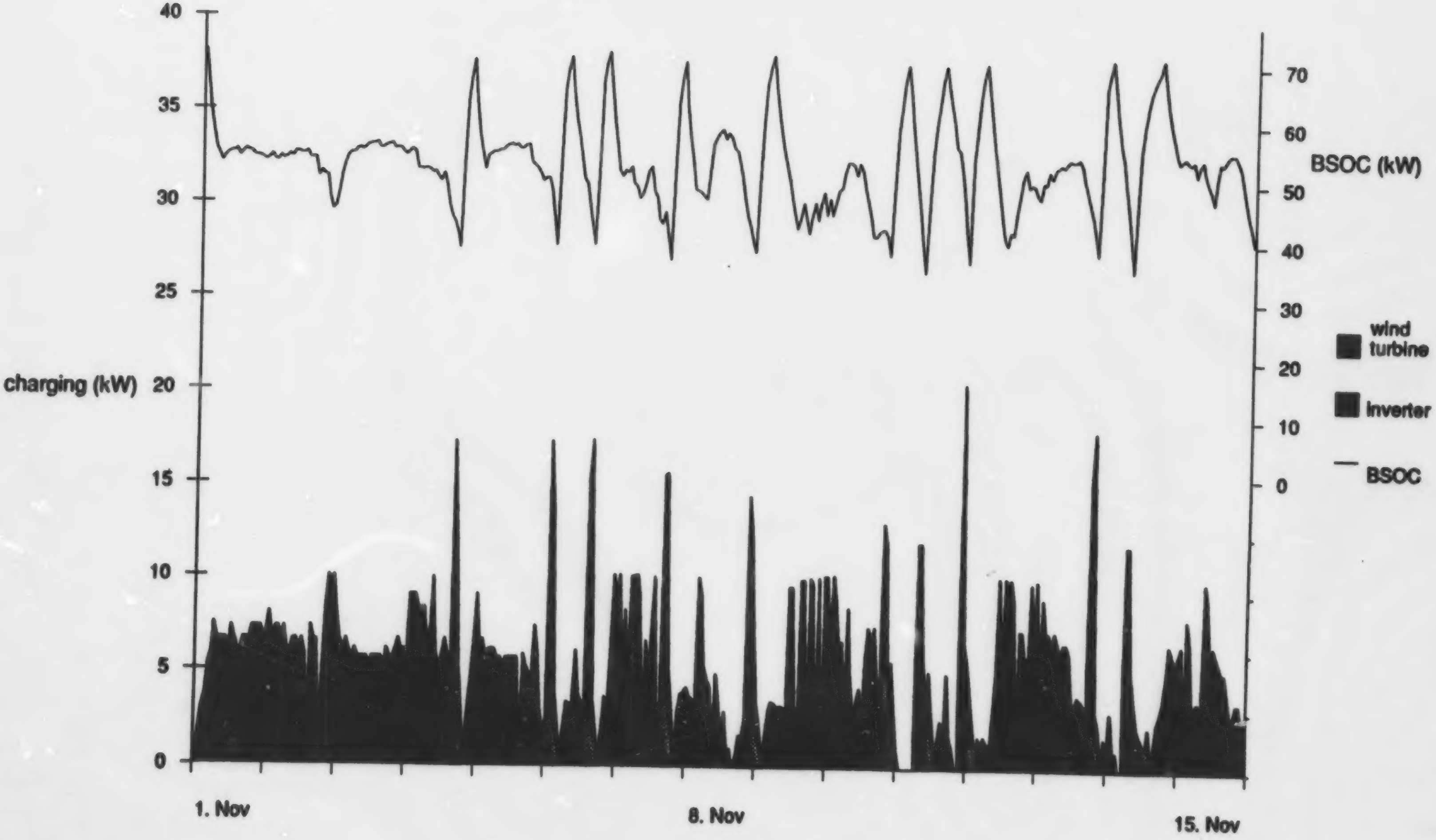


Figure 26

based on 60% of actual loads

Hindcast Battery Charging History (16. Nov - 30. Nov)

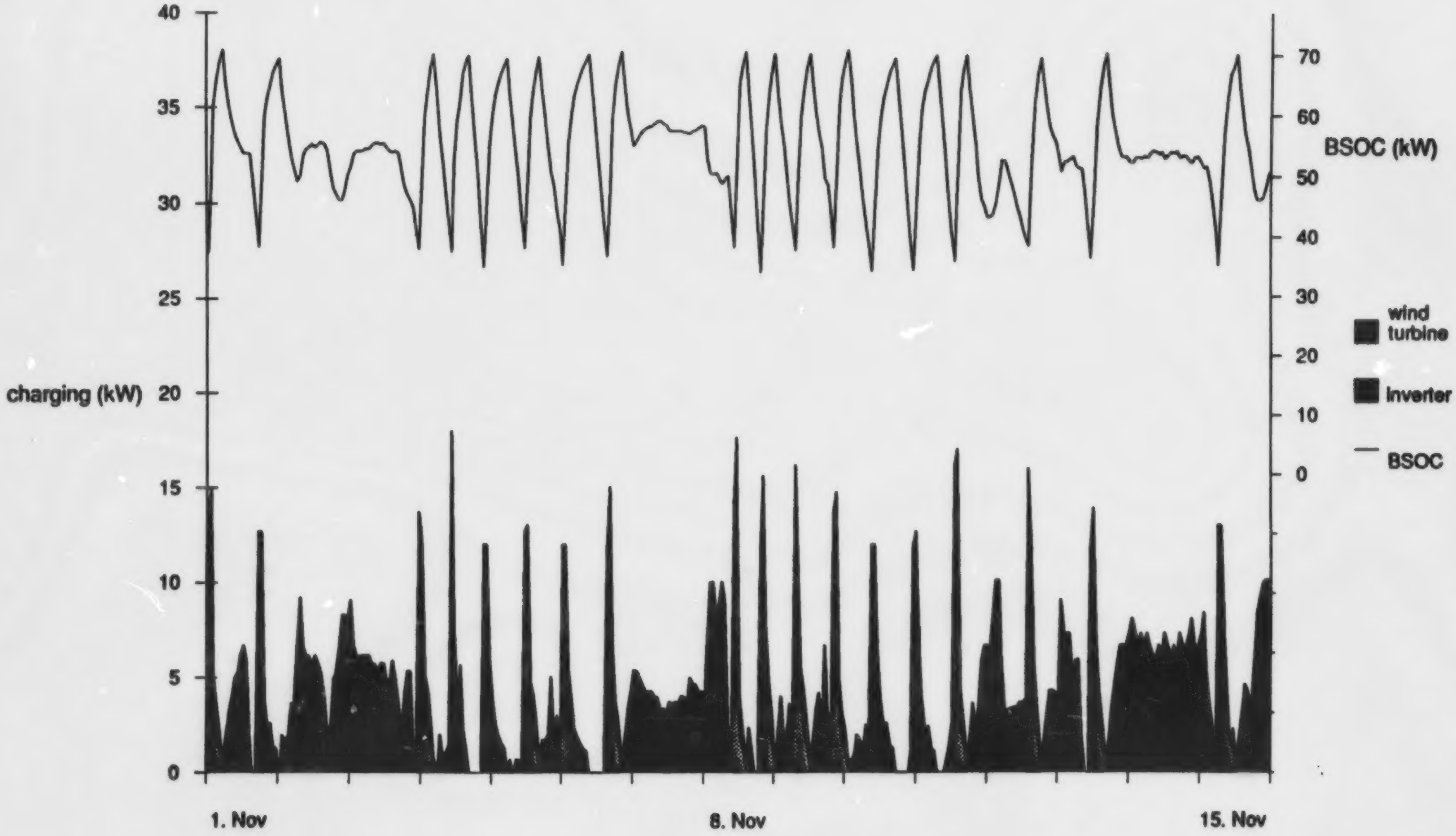


Figure 27

based on 60% of actual loads

Hindcast Load History (1. Nov - 15. Nov)

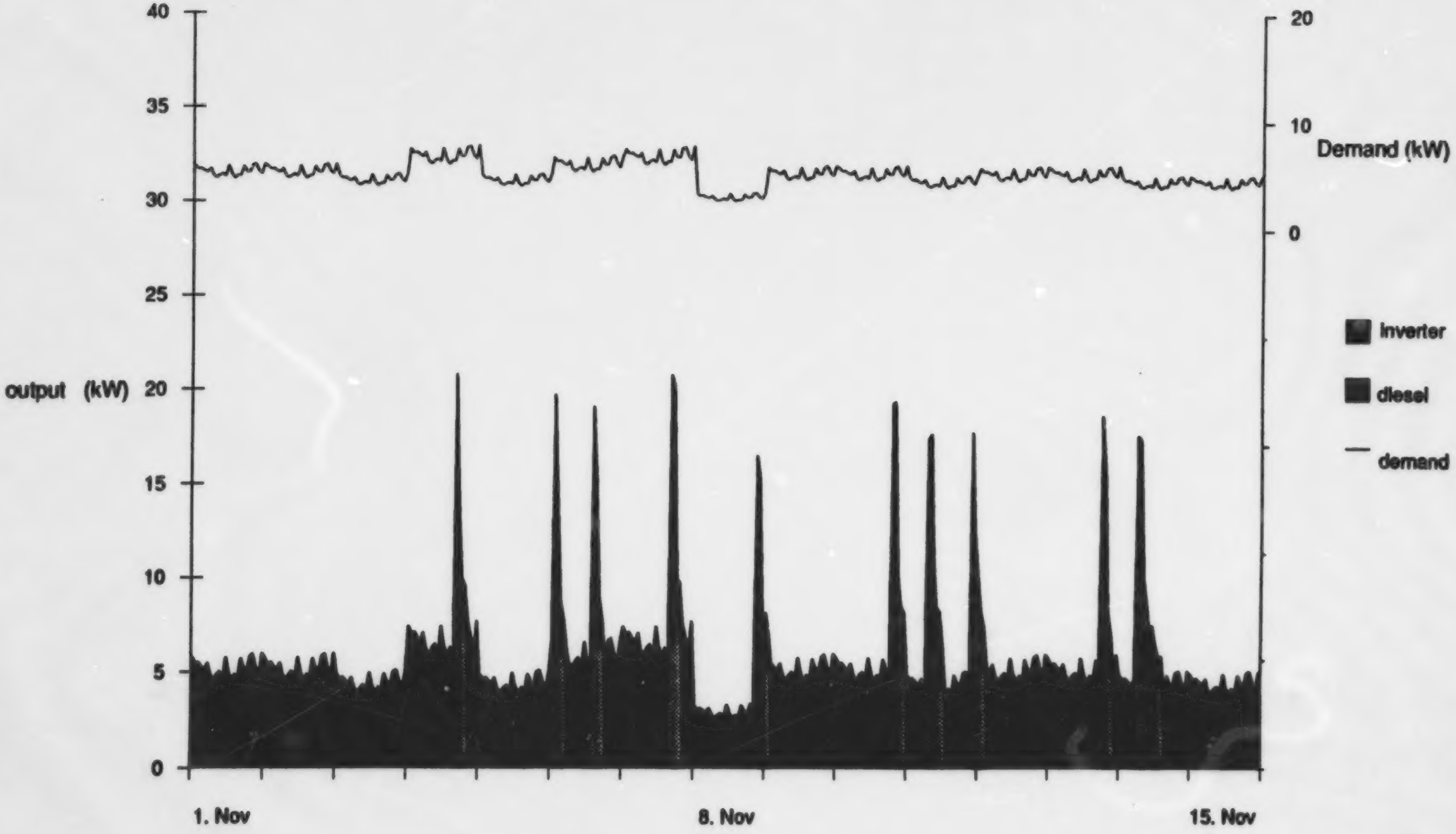


Figure 28

based on 60% of actual loads

Hindcast Load History (16. Nov - 30. Nov)

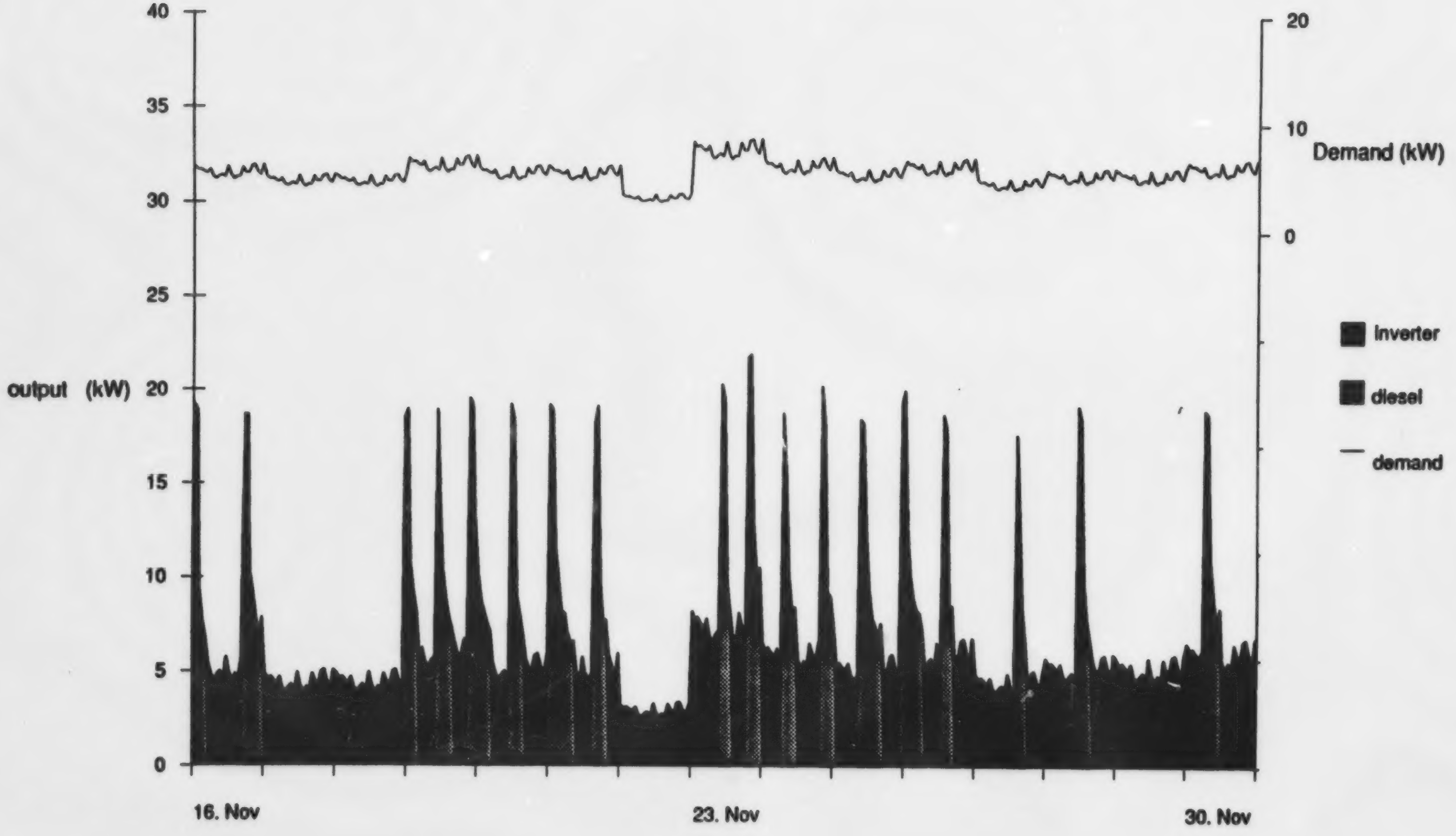


Figure 29

Table 8

Summary of Hindcast Analysis Results (actual loads w/ hybrid system)

Battery capacity= 77.000 kWh **actual loads**
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month	Windspeed (m/s)	Potential turbine output at site (kWh)	Actual turbine output (kWh)	Turbine utilization (%)	Load (kWh)	Average Demand (kW)	Diesel load (kWh)	Inverter charging load (kWh)	Inverter demand load (kWh)	Fuel used (l)	Fuel saved (l)	Fuel used w/ diesel only (l)	Diesel hours (hrs)	Diesel hours w/ diesel only (hrs)
May	5	1614	1159	71.8	6106	8.2	6017	2027	2474	2806	1056	3862	420	744
Jun	7	2722	1764	64.8	5926	8.2	5210	1683	2697	2458	1283	3741	373	720
Jul	5	1704	1238	72.6	5956	8.0	5783	2019	2527	2724	1108	3832	413	744
Aug	6	2248	1648	73.3	5745	7.7	5188	1812	2681	2445	1345	3790	371	744
Sep	6	2246	1725	76.8	4873	6.8	4235	1754	2683	2047	1484	3531	318	720
Oct	7	2436	1911	78.5	5114	6.9	4344	1771	2832	2066	1511	3577	315	744
Nov	10	3647	2280	62.5	6257	8.7	5099	1438	2858	2387	1421	3808	361	720
Dec	10	4009	902	22.5	7821	10.5	7505	759	1281	3678	545	4221	585	744
Jan	12	4498	791	17.6	7971	10.7	7684	614	1079	3790	464	4254	619	744
Feb	9	3355	1268	37.7	6768	10.1	6227	958	1724	2992	757	3749	472	672
Mar	8	2911	1557	53.5	6706	9.0	6124	1486	2359	2887	1014	3902	442	744
Apr	7	2843	898	31.8	7159	9.9	6961	1152	1589	3367	631	3998	533	720
TOTALS	8	34233	17139	55.3	76406	8.7	70396	17473	26784	33643	12621	46264	5232	8760

Table 8 (cont.)

Summary of Hindcast Analysis Results (60% of actual loads w/ hybrid system)

Battery capacity= 77.000 kWh   load management
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

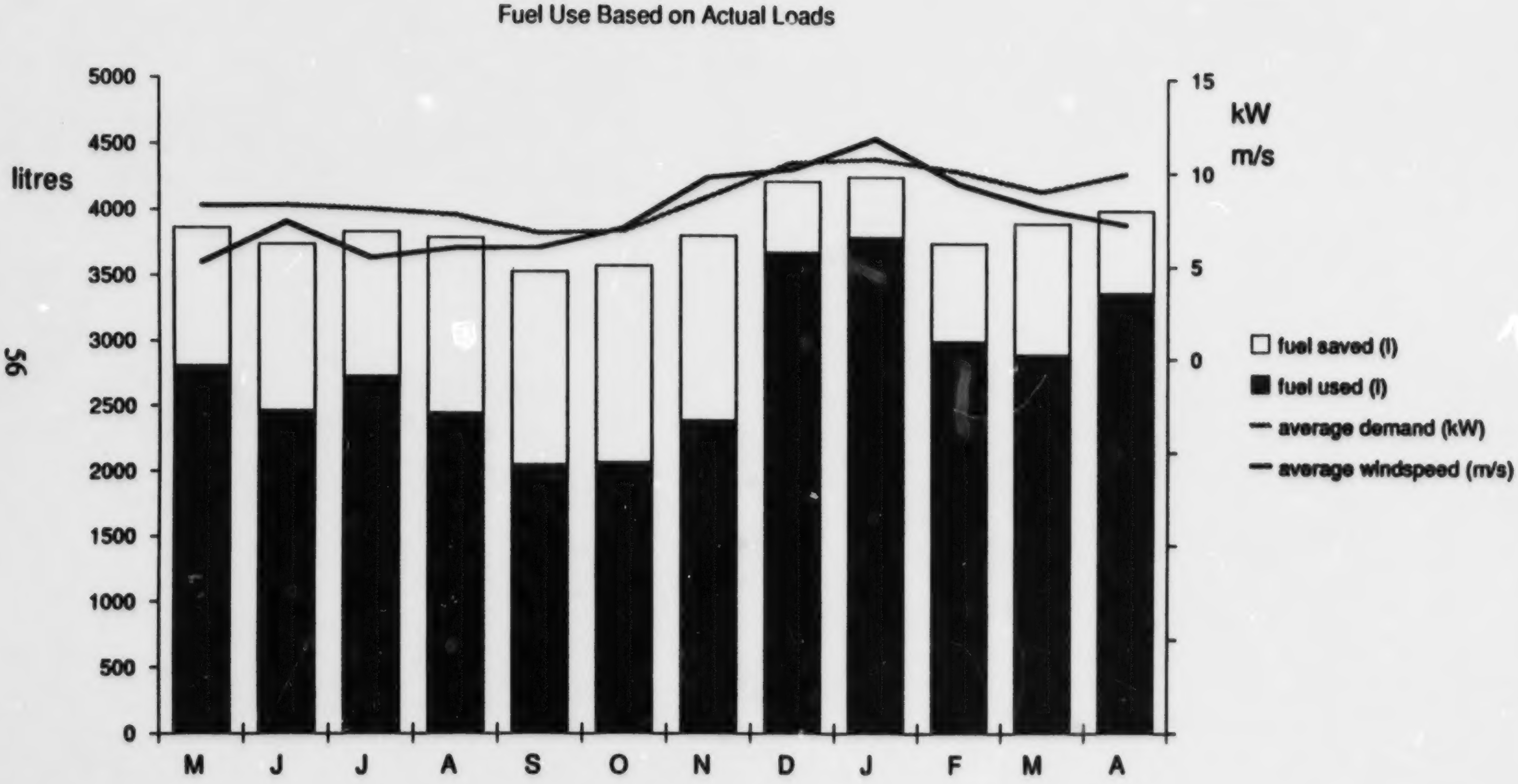
Month	Windspeed (m/s)	Potential turbine output at site (kWh)	Actual turbine output (kWh)	Turbine utilization (%)	Load (kWh)	Average Demand (kW)	Diesel load (kWh)	Inverter charging load (kWh)	Inverter demand load (kWh)	Fuel used (l)	Fuel saved (l)	Fuel used w/ diesel only (l)	Diesel hours (hrs)	Diesel hours w/ diesel only (hrs)
May	5	1614	1261	78.1	3688	5.0	3323	1562	2193	1749	1651	3400	294	744
Jun	7	2722	2088	76.7	3556	4.9	2465	1195	2481	1278	2010	3289	212	720
Jul	5	1704	1450	85.1	3574	4.8	3053	1465	2233	1607	1773	3381	270	744
Aug	6	2248	1738	77.3	3447	4.6	2668	1296	2294	1412	1946	3358	238	744
Sep	6	2246	1783	79.4	2924	4.1	1978	1016	2136	1095	2082	3178	191	720
Oct	7	2436	1748	71.8	3068	4.1	2194	1111	2172	1188	2014	3202	204	744
Nov	10	3647	2896	79.4	3754	5.2	1868	867	2895	946	2378	3324	154	720
Dec	10	4009	3100	77.3	4693	6.3	2781	1216	3323	1348	2235	3583	210	744
Jan	12	4496	3337	74.2	4783	6.4	2655	1184	3498	1274	2326	3599	198	744
Feb	9	3355	2633	78.5	4061	6.0	2459	1092	2870	1209	1995	3203	191	672
Mar	8	2911	2197	75.5	4025	5.4	2699	1346	2688	1441	1932	3373	230	744
Apr	7	2843	2377	83.6	4296	6.0	3009	1363	2871	1486	1936	3422	236	720
TOTALS	8	34233	26608	78.1	45868	5.2	31352	14715	31654	16034	24278	40312	2628	8760

Table 8 (cont.)

Summary of Hindcast Analysis Results (automated station loads w/ hybrid system)

Battery capacity= 77.000 kWh
Diesel capacity= 5.000 kW
Wind turbine capacity= 10.000 kW automatic station
Inverter capacity= 20.000 kW

Month	Windspeed (m/s)	Potential turbine output at site (kWh)	Actual turbine output (kWh)	Turbine utilization (%)	Load (kWh)	Average Demand (kW)	Diesel load (kWh)	Inverter charging load (kWh)	Inverter demand load (kWh)	Fuel used (l)	Fuel saved (l)	Fuel used w/ diesel only (l)	Diesel hours (hrs)	Diesel hours w/ diesel only (hrs)
May	5	1542	927	60.1	1126	1.5	591	352	905	610	2274	2885	137	744
Jun	7	2722	1242	45.6	1126	1.6	312	191	1012	321	2563	2885	72	720
Jul	5	1704	1086	63.7	1162	1.6	509	310	977	522	2458	2980	117	744
Aug	6	2248	1109	49.3	1162	1.6	491	301	968	508	2473	2980	114	744
Sep	6	2246	1074	47.8	1126	1.6	492	301	947	504	2380	2885	113	720
Oct	7	2523	1281	50.8	1162	1.6	339	211	1042	348	2632	2980	78	744
Nov	10	3647	1377	37.8	1126	1.6	204	120	1046	210	2675	2885	47	720
Dec	10	4009	1530	38.2	1162	1.6	115	68	1117	116	2864	2980	26	744
Jan	12	4498	1579	35.1	1162	1.6	70	36	1129	72	2908	2980	16	744
Feb	9	3355	1339	39.9	1054	1.6	133	82	1007	138	2555	2693	31	672
Mar	8	2911	1285	44.1	1126	1.5	296	180	1018	304	2581	2885	68	744
Apr	7	2843	1255	44.1	1126	1.6	312	180	1003	321	2564	2885	72	720
TOTALS	8	34247	15084	46.4	13614	1.6	3866	2331	12186	3974	30929	34903	891	8760



Fuel Use Based on Actual Loads

Figure 30

the fuel use and savings using the actual loads on a monthly basis. In comparison Figure 31 shows the fuel use history based on load management. The reduction in loads has a significant effect on the impact of the hybrid system in fuel use. The comparison of fuel use of the present system and the hybrid system with load management is given in Figure 32.

Besides the reduction in fuel use, the hybrid system also has a significant effect in reducing the diesel operating hours as shown in Figure 33. This in turn should have an effect on the number of servicings required. Based on the actual average number of hours between servicing of the study year (230.5), the estimated number of servicings required are shown in Figure 34. This reduction in the number of servicings required will have a major impact on O&M costs.

It is interesting to note in the results that with the present loads there is a direct correlation between the average demand and the percentage of turbine utilization (actual turbine output vs. potential turbine output). However with the reduced loads there is no correlation. Figures 35 and 36 illustrate this. Turbine utilization can actually be seen to decrease as the loads increase in Figure 35. Two factors contribute to this. At higher average demands there are more instances where the demand is exceeding 50% of the inverter capacity and the diesel is required to operate. Whenever the diesel is started it operates until the battery state of charge reaches 90%, therefore at high demands the diesel is charging the batteries more often and there is increased likelihood of the battery state of charge being high enough to prevent full utilization of the available wind power (especially at higher wind speeds when charge regulation may be required). This indicates that the hybrid system is not large enough for the full load situation. However the total lack of any relationship between demand and utilization at the reduced load level (Figure 36), and the similarity in the wind turbine utilization pattern for both average demand and wind speed, indicates that the system is adequately sized for this situation. This is further indicated by the wind turbine utilization ranging from 70% to 90% in the reduced load scenario as opposed to 15% to 80% in the full load situation. The converse may also be expected; if the turbine is oversized its utilization would also be lower, especially at higher wind speeds.

Fuel Use Based on Load Management

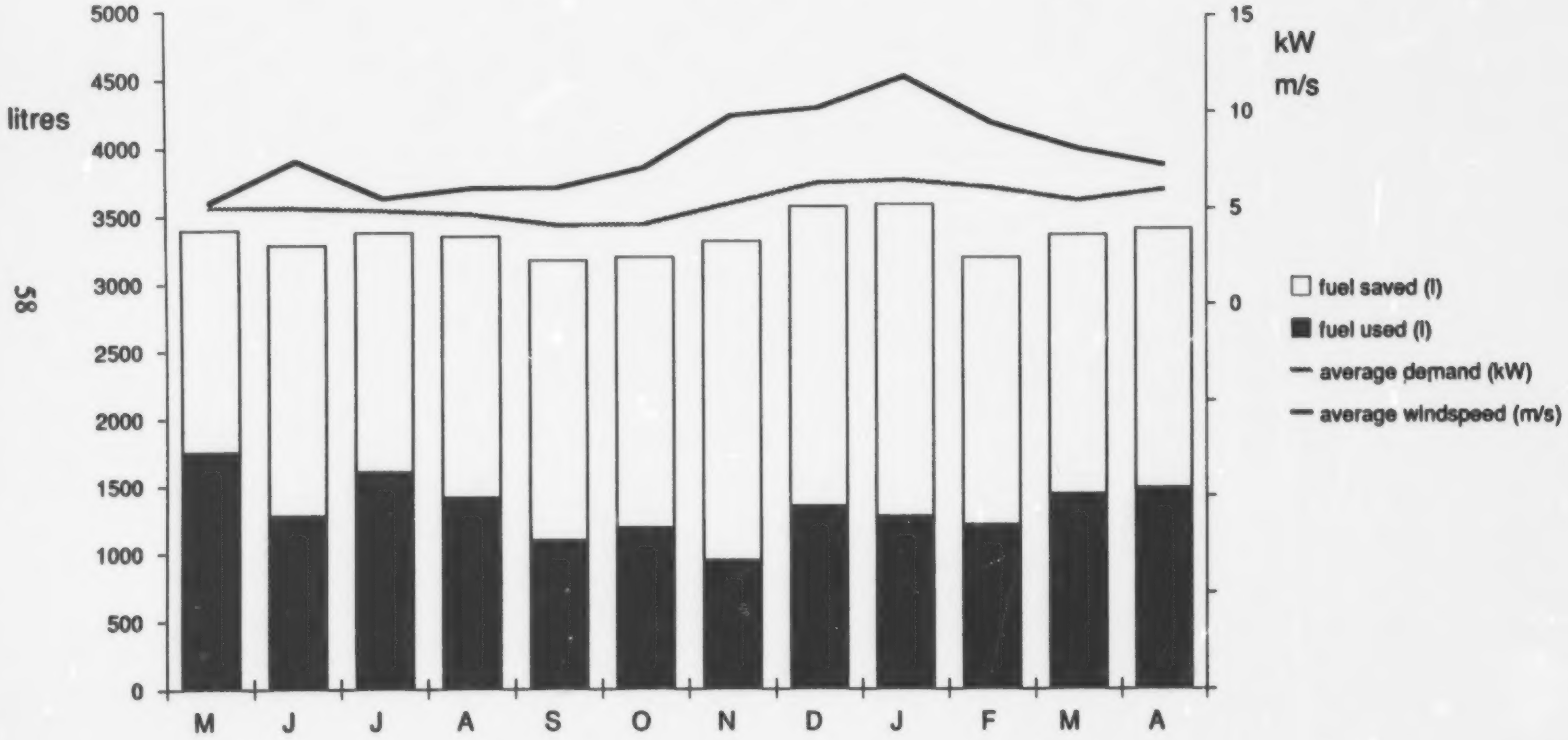


Figure 31

Fuel Use Comparison of Present and Hybrid Systems

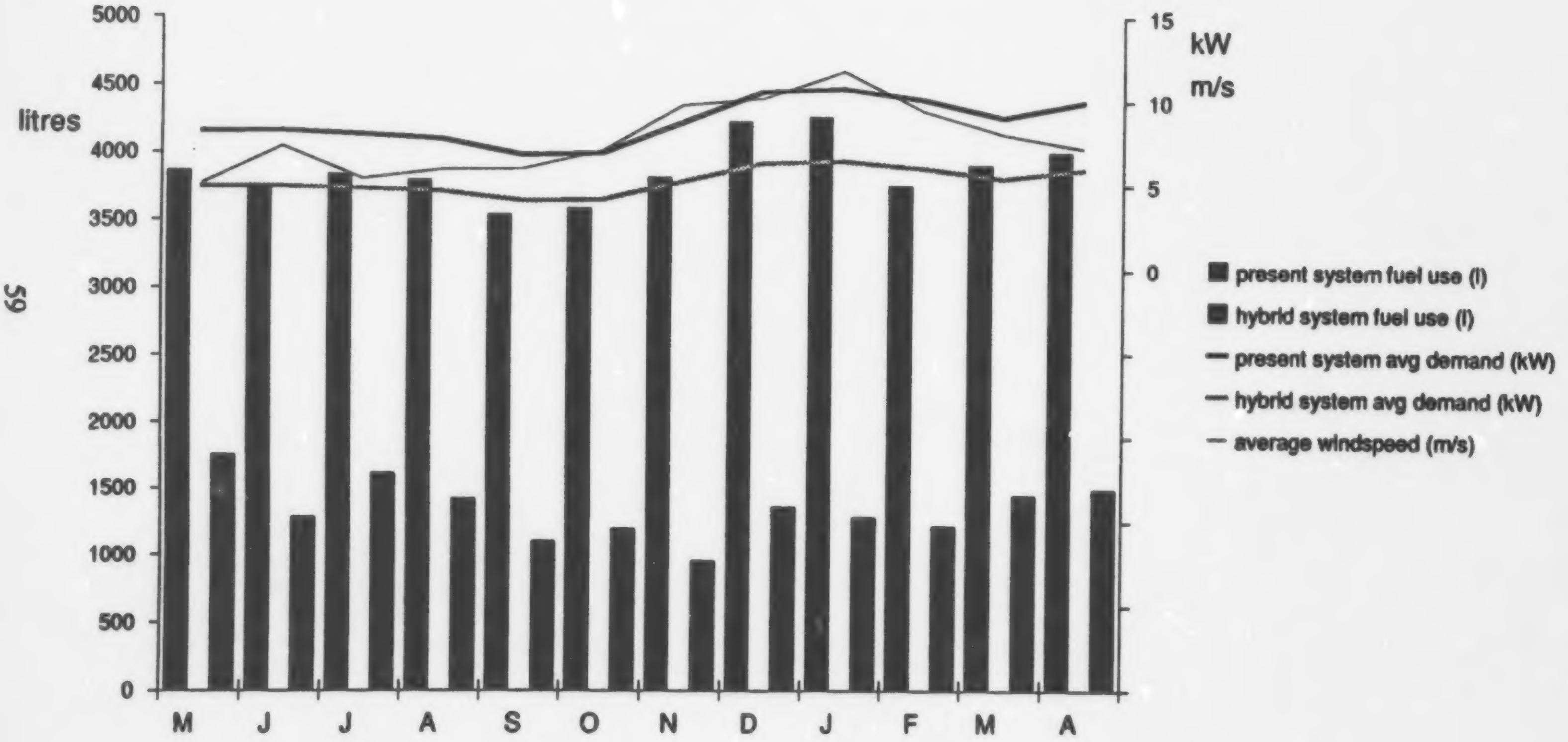


Figure 32

Diesel Hours of Present and Hybrid Systems

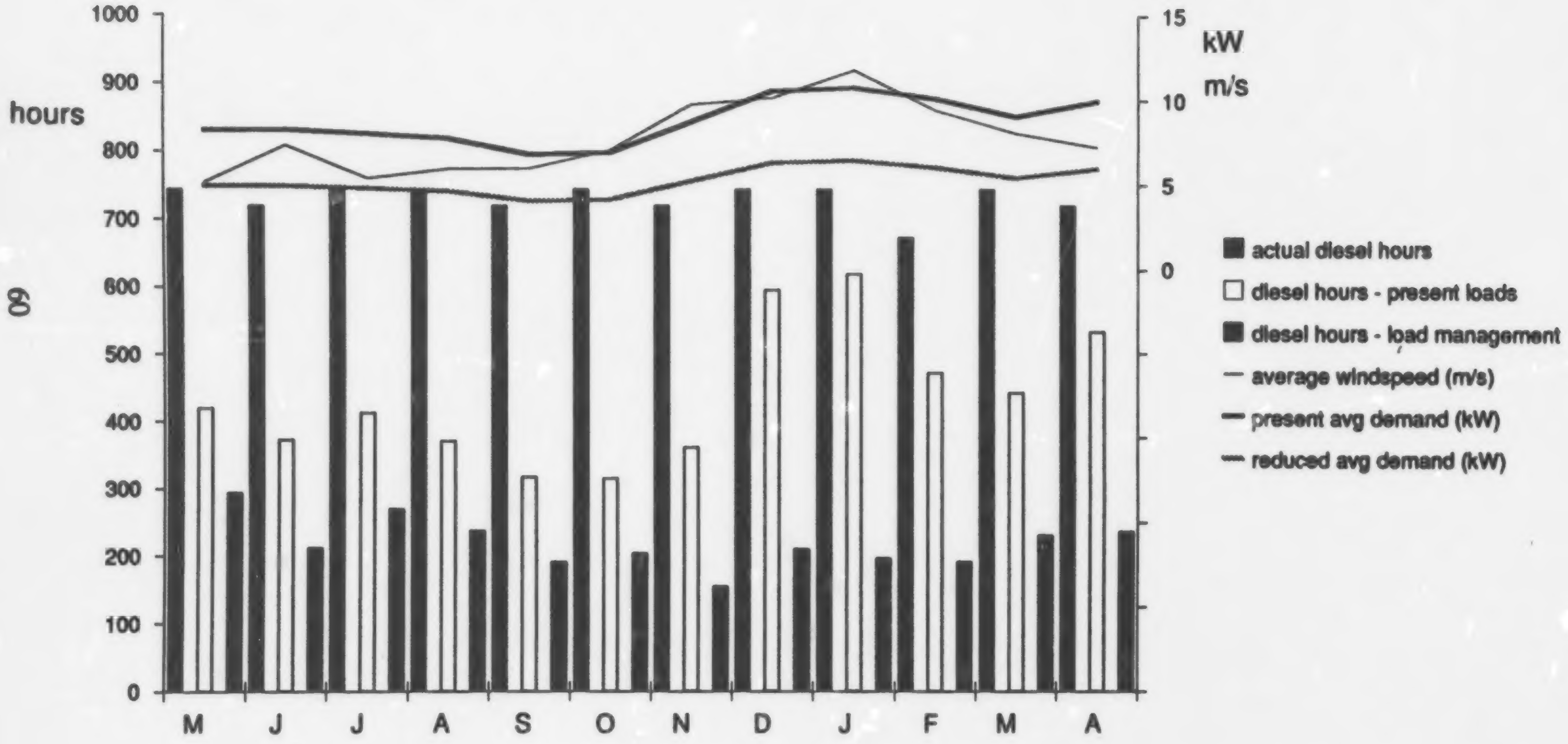


Figure 33

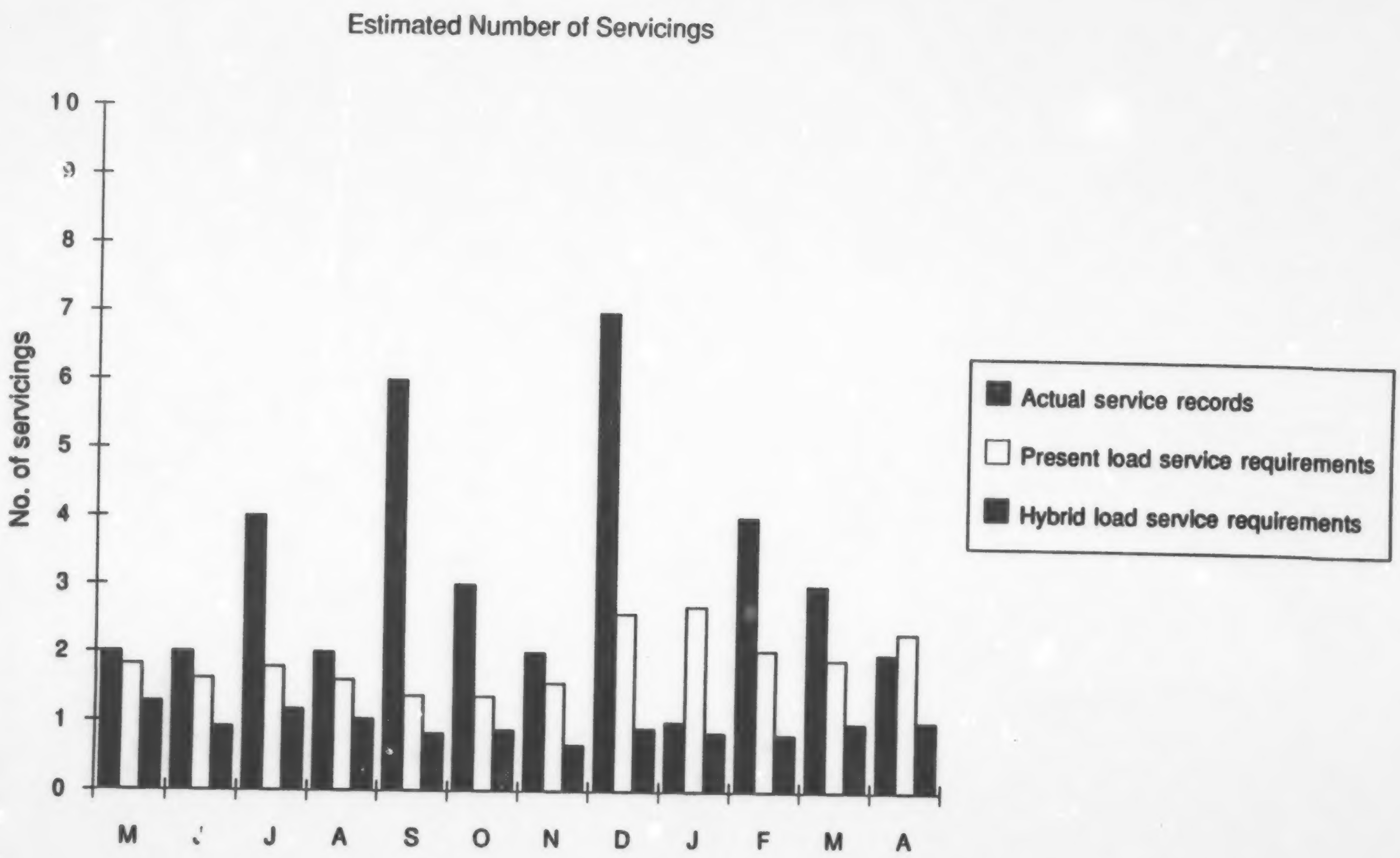

Estimated Number of Servicings
No. of servicings
10
9
8
7
6
5
4
3
2
1
0
M
J
J
A
S
O
N
D
J
F
M
A
Actual service records
Present load service requirements
Hybrid load service requirements

Figure 34

Effect of Loads and Windspeed on Turbine Utilization

Present Loads

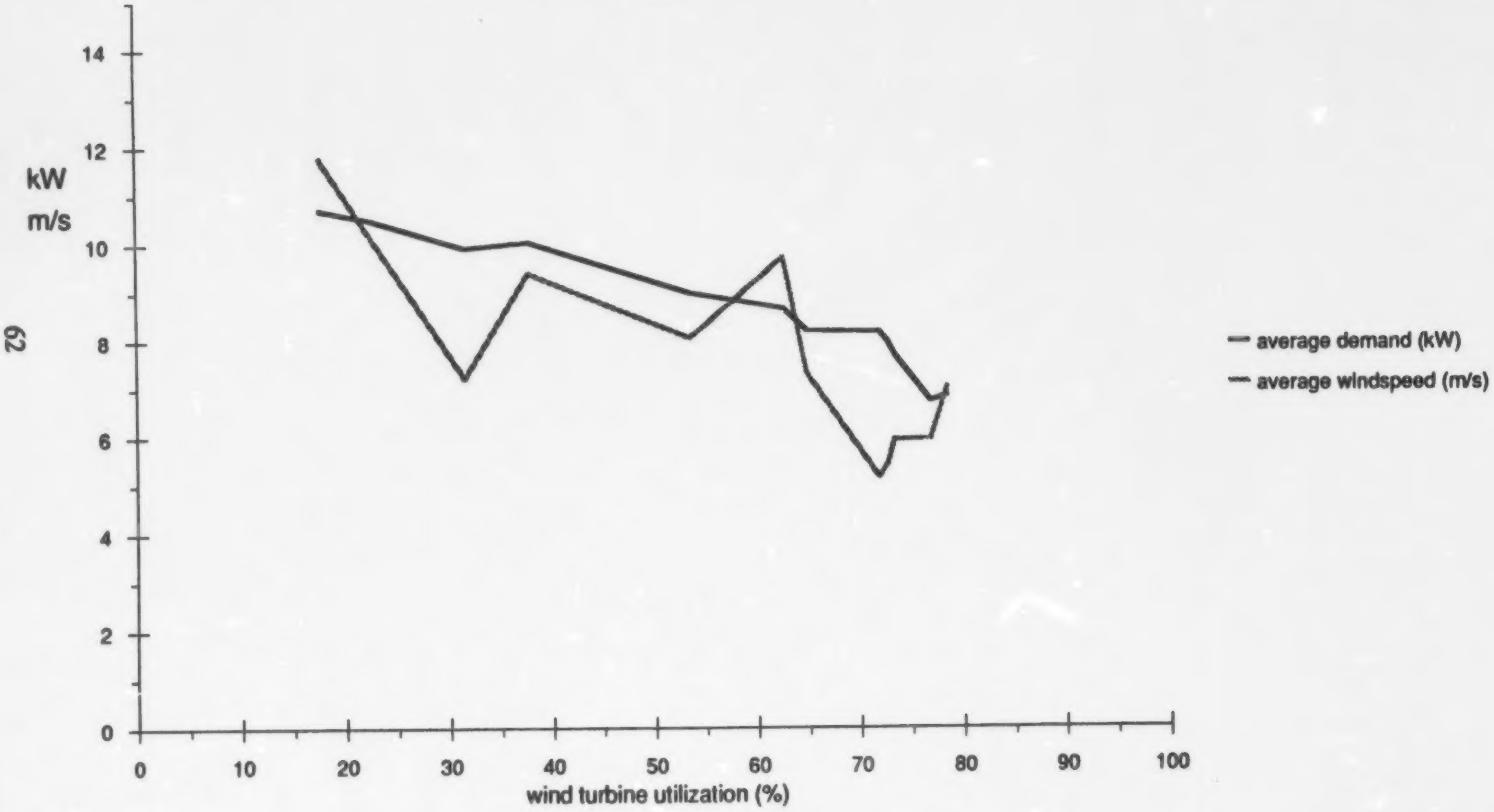


Figure 35

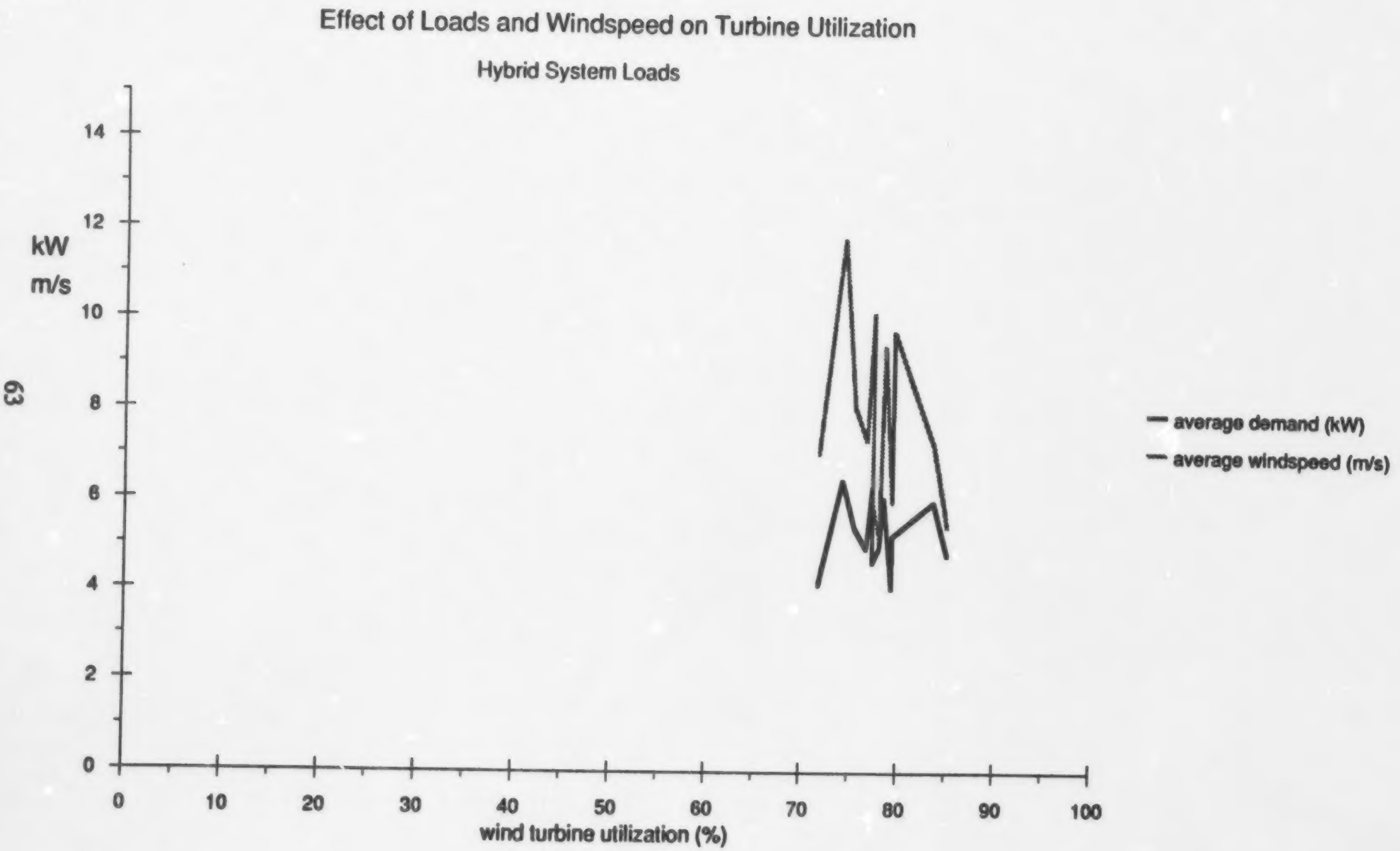

Effect of Loads and Windspeed on Turbine Utilization
Hybrid System Loads
kW
m/s
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
wind turbine utilization (%)
average demand (kW)
average windspeed (m/s)

Figure 36

9.0 Simple Economic Analysis

In order to truly evaluate the consequences of the fuel savings and reduced O&M costs, life cycle cost analyses are required. The following analyses were performed in the standard manner typically used for renewable energy projects[6]. These analyses assumed a fuel cost of $0.80/litre, which is typical of many remote sites. It should be noted however that AES actually only pays the bulk fuel cost at the port, the transportation costs are covered by Transport Canada. However, these costs are real and are being incurred, although not by AES. It would be unrealistic to assume the cost of fuel at a site such as Cape St. James is equivalent to the cost of fuel at the bulk facilities in Prince Rupert. If these unrealistic fuel costs were used they would reduce the total life cycle cost savings in the automated station scenario to approximately $275,000 or 47% from the values discussed in the following.

Table 9 gives the life cycle economic analysis assuming that the present site loads remain unchanged. As is seen in the table there is little difference in the total life cycle cost between the present system and the addition of the hybrid system.

If it is assumed that the loads can be reduced when the hybrid system is installed, a significant life cycle cost savings can be realized (Table 10). The net savings resulting from the installation of the hybrid system is $422,853 or 42%.

Table 11 gives the results of the analysis based on the assumption that the station is automated. Even though the capital cost of the hybrid system is significantly greater than that of the diesel system a substantial life cycle cost savings can still be realized by the installation of the hybrid system ($557,273 or 62%).

Simple payback in all cases, though a crude measurement parameter, provides a simplified method of determining at what point in time the specified system 'pays back' its initial Capital cost; this is not necessarily related to the differences in Total Life Cycle Costs between the existing and the hybrid system.

Table 9

Advanced Wind Diesel Hybrid

Example Life Cycle Economic Analysis and Simple Payback Calculations for present loads

Economic Parameters

System life = 20 yrs
Loan interest rate = 10 %
Investment rate = 10 %
Inflation rate = 5 %
Fuel inflation rate = 8 %
Net discount rate = 5 % (investment rate - inflation rate)
Net fuel discount rate = 2 % (investment rate - fuel inflation rate)

Basic Costs [1]	Advanced Hybrid System	Stand-alone Diesel System
Capital	$160,530	existing
Salvage (10%) [2]	($16,053)	($6,000)
Annual hours of diesel operation	5,232	8,760
Annual maintenance [3]	$17,619	$29,500
Annual fuel consumption (litres)	33,643	46,264
Annual fuel cost	$26,914	$37,011
Engine rebuild cost	$0	$15,000
Generator rebuild cost	$8,000	$8,000
Battery replacement	$35,000	$0
Present Worth [4]		
Capital (20 yearly payments) [5]	$231,661	$0
Maintenance costs [6]	$219,570	$367,629
Energy Costs [7]	$440,077	$605,170
Engine rebuild (year 6, 13, 20) [8]	$14,809	$24,795
Generator rebuild (year 10) [8]	$0	$4,456
Hybrid system rebuild (year 10) [8]	$4,456	$0
Battery replacement (year 10) [8]	$19,495	$0
Salvage value [9]	($6,052)	($2,262)
Total Life Cycle Cost	$924,016	$999,788
Simple Payback [9]	7.78 yrs	

Notes:

1. Costs in Current Dollars of individual components of the installed systems.
2. Low salvage values reflect cost to remove.
3. Includes transportation and accomodation of maintenance crew.
4. Present Value of individual costs over the life of the two systems.
5. 20 annual payments of principal and 10% interest at a net discount rate of 5%.
6. 20 annual payments for maintenance at a net discount rate of 5% (Uniform PWF).
7. 20 annual payments for fuel at a net discount rate of 2% (Uniform PWF).
8. Single payments for rebuilds or replacements at a net discount rate of 5% (Single PWF).
9. Single receipt for salvage at end of 20 years at net discount rate of 5% (Single PWF).
9. Total Cost of Hybrid System divided by annual Diesel Costs less the annual hybrid costs.
Payback Calculations do not consider alternate investments, discounted values for money, etc.

Table 10

Advanced Wind Diesel Hybrid

Example Life Cycle Economic Analysis and Simple Payback Calculations for reduced loads with hybrid system

Economic Parameters	
System life =	20 yrs
Loan interest rate =	10 %
Investment rate =	10 %
Inflation rate =	5 %
Fuel inflation rate =	8 %
Net discount rate =	5 % (investment rate - inflation rate)
Net fuel discount rate =	2 % (investment rate - fuel inflation rate)

Basic Costs [1]	Advanced Hybrid System	Stand-alone Diesel System
Capital	$160,530	existing
Salvage (10%) [2]	($16,053)	($6,000)
Annual hours of diesel operation	2,626	8,760
Annual maintenance [3]	$8,843	$29,500
Annual fuel consumption (litres)	16,034	46,264
Annual fuel cost	$12,827	$37,011
Engine rebuild cost	$0	$15,000
Generator rebuild cost	$8,000	$8,000
Battery replacement	$35,000	$0
Present Worth [4]		
Capital (20 yearly payments) [5]	$231,661	$0
Maintenance costs [6]	$110,205	$367,629
Energy Costs [7]	$209,738	$605,170
Engine rebuild (year 6, 13, 20) [8]	$7,433	$24,795
Generator rebuild (year 10) [8]	$0	$4,456
Hybrid system rebuild (year 10) [8]	$4,456	$0
Battery replacement (year 10) [8]	$19,495	$0
Salvage value [9]	($6,052)	($2,262)
Total Life Cycle Cost	$576,935	$999,788
Simple Payback [9]	3.69 yrs	

Notes:

1. Costs in Current Dollars of individual components of the installed systems.
2. Low salvage values reflect cost to remove.
3. Includes transportation and accomodation of maintenance crew.
4. Present Value of individual costs over the life of the two systems.
5. 20 annual payments of principal and 10% interest at a net discount rate of 5%.
6. 20 annual payments for maintenance at a net discount rate of 5% (Uniform PWF).
7. 20 annual payments for fuel at a net discount rate of 2% (Uniform PWF).
8. Single payments for rebuilds or replacements at a net discount rate of 5% (Single PWF).
9. Single receipt for salvage at end of 20 years at net discount rate of 5% (Single PWF).
9. Total Cost of Hybrid System divided by annual Diesel Costs less the annual hybrid costs.
   Payback Calculations do not consider alternate investments, discounted values for money, etc.

Table 11

Advanced Wind Diesel Hybrid
Example Life Cycle Economic Analysis and Simple Payback Calculations for automated station

Economic Parameters
System life = 20 yrs
Loan interest rate = 10 %
Investment rate = 10 %
Inflation rate = 5 %
Fuel inflation rate = 8 %
Net discount rate = 5 % (investment rate - inflation rate)
Net fuel discount rate = 2 % (investment rate - fuel inflation rate)

Basic Costs [1]	Advanced Hybrid System	Stand-alone Diesel System
Capital	$160,530	$42,000
Salvage (10%) [2]	($16,053)	($4,200)
Annual hours of diesel operation	891	8,760
Annual maintenance [3]	$3,001	$29,500
Annual fuel consumption (litres)	3,974	34,903
Annual fuel cost	$3,179	$27,922
Engine rebuild cost	$0	$8,000
Generator rebuild cost	$8,000	$2,000
Battery replacement	$35,000	$0
Present Worth [4]		
Capital (20 yearly payments) [5]	$231,661	$60,610
Maintenance costs [6]	$37,392	$367,629
Energy Costs [7]	$51,983	$456,559
Engine rebuild (year 6, 13, 20) [8]	$1,345	$13,224
Generator rebuild (year 10) [8]	$0	$1,114
Hybrid system rebuild (year 10) [8]	$4,456	$0
Battery replacement (year 10) [8]	$19,495	$0
Salvage value [9]	($6,052)	($1,583)
Total Life Cycle Cost	$340,280	$897,553
Simple Payback [9]	3.28 yrs	

Notes:

1. Costs in Current Dollars of individual components of the installed systems.
2. Low salvage values reflect cost to remove.
3. Includes transportation and accomodation of maintenance crew.
4. Present Value of individual costs over the life of the two systems.
5. 20 annual payments of principal and 10% interest at a net discount rate of 5%.
6. 20 annual payments for maintenance at a net discount rate of 5% (Uniform PWF).
7. 20 annual payments for fuel at a net discount rate of 2% (Uniform PWF).
8. Single payments for rebuilds or replacements at a net discount rate of 5% (Single PWF).
9. Single receipt for salvage at end of 20 years at net discount rate of 5% (Single PWF).
9. Total Cost of Hybrid System divided by annual Diesel Costs less the annual hybrid costs.
Payback Calculations do not consider alternate investments, discounted values for money, etc.

10.0 Environmental issues

The reduction in fuel use and diesel engine operating times with the advanced hybrid system results in a number of positive effects environmentally.

Diesel fuel use with the system, using load management ,results in a 65% reduction in annual fuel use, from over 46,000 litres used annually to 16,000 litres. This fuel use reduction is important for several reasons:

- Emissions annually are reduced by at least the same amount, 65%. In fact, emissions are likely reduced even more, because the diesel engines under the hybrid system with load management are operated at higher efficiencies. It is estimated that total emissions avoided in this situation are, at a minimum, 12,321 kg total per year, and consist of a variety of emission types as shown in Table 12.

Table 12
Diesel Fuel Use Emissions

Emission	Emissions Rates [7]				kg per 30,000 litres
NOx	1100	Tonnes/PJ	0.04257	kg/litre	1277.1
SO2	61	Tonnes/PJ	0.0023607	kg/litre	70.821
VOCs	88	Tonnes/PJ	0.0034056	kg/litre	102.168
Methane [CH4]	12.5	Tonnes/PJ	0.00048375	kg/litre	15.513
CO2	70.7	Tonnes/TJ	0.273609	kg/litre	8208.27
COx	19.3	Tonnes/TJ	0.074691	kg/litre	2240.73
CO	350	Tonnes/PJ	0.013545	kg/litre	406.35
N2O	0.035	Tonnes/PJ	0.000001355	kg/litre	0.040635
				Total =	12320.99

Conversion Factors [8]

Energy Content of diesel fuel	38.7	GJ/m3
	38.7	GJ/1000 litres
	1 PJ =	1,000,000 GJ
	1 TJ =	10,000 GJ

- The amount of fuel which must be stored on site is reduced by a large degree, reducing the risk of leakage, on-site spillage, vapour releases and storage space requirements.
- The amount of fuel which must be transported to the site is also reduced, which lowers the hazards associated with barging, loading and unloading. With correct storage conditions and precautions, delivery of fuel can be scheduled for once every two years, instead of every year, reducing this hazard by 50%. Further reductions, with appropriate storage approaches, may be possible.

The above calculations are based on the use of light commercial diesel fuel; the use of heavier fuels, such as bunker-type diesels, result in higher emissions, and the annual reductions using the hybrid system would be even more significant.

The reductions in diesel engine operating times save money and labour, but also reduce the amounts of used lubricants and spent consumables such as filters, seals and coolant which must be disposed of. As well, the 70% reduction in operating times results in the equivalent amount of time without the noise and fumes of the diesel engines, and a similar degree of reduction in impacts on wildlife, vegetation, marine life, and the humans living or visiting the site. However, it must be pointed out that noise impact from the diesels may not be directly of significance to local wildlife, as the ambient noise levels of wind and ocean mask much of the noise, except adjacent to the diesel facility.

There are impacts of the proposed wind system. Noise is generated by a wind turbine rotating in the wind, however it, too, will be almost completely masked by ambient wind and sea noise. There are visual impacts resulting from the erection of the tower to support the wind turbine; this is not of great significance since three towers already exist on the same portion of the island. There is minimal or no terrain disturbance which would result from the installation of the wind turbine, as the proposed site is on a slope which was paved with asphalt in the past for rainwater collection.

11.0 Conclusions

This project provided the opportunity to evaluate a new concept in wind/diesel hybrid system design and operation, using historical information for an actual site, by the use of hindcast analysis methods.

From the work conducted, we conclude that:

- The Advanced Wind/Diesel Hybrid System substantially reduces diesel fuel use and engine run times. The fuel savings are typically 65% and run times are reduced by 70%, over full time operation of the diesel engine generators.
- The capability of the Advanced Wind/Diesel Hybrid System to synchronize the DC-Inverter supply to the diesel generator for peaking purposes was demonstrated in the Automatic System to allow for a reduction in diesel generator size by 50%, which also results in decreased fuel use and higher efficiencies.
- The prediction of reduced maintenance efforts and associated costs was confirmed, with scheduled servicings of the diesels in the load management scenario down 68% from 38 to 12 annually.
- The overall efficiency of the system was raised from a range of 10 to 30% (based on the diesel capacity level) to an average of 86% (based on batteries at 85%, diesels at 90%, wind at 78.1%, inverter/charger at 90%).
- The study showed that the smallest possible battery bank design that is compatible with the charge/discharge rates to be imposed should be used, resulting in capital cost savings for these components.
- The hindcast analysis tool can be effective in determining if the hybrid system and/or wind turbine has been correctly sized for the loads and wind regime.
- The lifecycle cost savings of installing the hybrid system, with simple load management, results in 47% savings over current usage, and 62% for a hybrid system compared to a typical 100% runtime diesel system for an automated station scenario.
- The environmental benefits of replacing the full time diesels with the hybrid system are estimated to amount, conservatively, to avoided emissions totalling over 12 tonnes annually. The avoided emissions include NO_X,

SO_2, Volatile Organic Compounds [VOCs], CH_4, various carbon coefficients including CO and CO_2, and N_2O.

- A general conclusion is that the Advanced Wind/Diesel Hybrid System is likely to be suitable, subject to verification in an actual Canadian installation, for use at a number of remote diesel sites with sufficient wind resources, for the purposes of cost, fuel, and environmental savings.

There are several areas which were inconclusive, and will require verification in other ways. These include:

- determining the advantage of synchronizing the DC-Inverter with the diesel for the larger, manned, system, although it showed up in the automated design (see above). If 'done from scratch', the approach would be to remove existing diesels or start with optimum sized ones, and this analysis tool would be able to do that. For example, at this site it is likely the optimum diesel capacity would be about 10 kW.
- the retro fit capability of the advanced system can not be tested in such a study, but requires actual equipment installation to verify.

12.0 Recommendations

It is recommended that the sources of inaccuracy or error which were determined during this study be verified, as well as the firm results, by installing the actual equipment in a realistic situation and monitoring it for over a year. In particular, the ability to use smaller generators than would otherwise be required, the synchronizing capabilities of the controls, and the ability to retro fit existing generators require this type of verification.

This should be done by assembling an idealized design, installing it at a location suitable for wind energy and monitoring capability, such as the Atlantic Wind Test Site, and involving the test site staff in monitoring, operating, trouble shooting and advising.

The analysis tool should also be used to directly compare the Advanced Wind /Diesel hybrid to standard wind diesel methodologies, as well as diesel only cycle charging systems.

13.0 References

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[2] Canadian Standards Association, *CSA preliminary Standard F417-M1986, Wind Energy Conversion Systems (WECS) - Performance*, Section 6.5.3.1, March, 1986.

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[4] Atmospheric Environment Service, Environment Canada, *Canadian Climate Normals, Volume 5, Wind, 1951-1980*, p. 2, 1982.

[5] pers. comm D. Watson, Atmospheric Environment Service, Environment Canada.

[6] CANMET, Energy, Mines and Resources Canada, *Canadian Small Hydropower Handbook: British Colombia Region*, 1989.

Energy, Mines and Resources Canada, *Photovoltaic Systems Design Manual*, 1989.

7 EMR Canada, Ad Hoc Committee on Emission Factors, *Emission Factors for Greenhouse and Other Gases by Fuel Type: An Inventory*, 1990.

8 ERCB Alberta, *Energy Requirements in Alberta, Supplementary Report 1989-2003*, 1989.

Appendices

Appendix A	Monthly Load Records (May, 1989 - May, 1990)
Appendix B	Example Hindcast Analysis Output (November)
Appendix C	Monthly Analysis Graphs

Appendix A

Monthly Load Records (May, 1989 - May, 1990)

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-May-89	D359	5550	370	-	11.10	serviced & started
2-May-89	D359	5556	370	180	11.10	
3-May-89	D359	5562	335	180	10.05	
4-May-89	D359	5568	320	180	9.60	
5-May-89	D359	5574	420	180	12.60	
6-May-89	D359	5581	365	210	10.95	
7-May-89	D359	5586	360	150	10.80	
8-May-89	D359	5593	360	210	10.80	
9-May-89	D359	5600	380	210	11.40	
10-May-89	D359	5606	430	180	12.90	
11-May-89	D359	5613	405	210	12.15	
12-May-89	D359	5620	490	210	14.70	
13-May-89	D359	5622	305	60	9.15	
14-May-89	D359	5629	380	210	11.40	
15-May-89	D359	5636	360	210	10.80	
16-May-89	D359	5644	400	240	12.00	
17-May-89	D359	5651	425	210	12.75	
18-May-89	D359	5659	440	240	13.20	
19-May-89	D359	5665	410	180	12.30	
20-May-89	D359/357	5671	390	180	11.70	service/switched
21-May-89	D357	5679	500	240	15.00	
22-May-89	D357	5686	360	210	10.80	
23-May-89	D357	5694	575	240	17.25	
24-May-89	D357	5702	420	240	12.60	
25-May-89	D357	5709	460	210	13.80	
26-May-89	D357	5717	525	240	15.75	
27-May-89	D357	5723	520	180	15.60	
28-May-89	D357	5731	390	240	11.70	
29-May-89	D357	5735	345	120	10.35	
30-May-89	D357	5741	440	180	13.20	
31-May-89	D357	5747	380	180	11.40	
Total				5910	-	2
Average				197	12.22	
Max				240	17.25	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Jun-89	D357	5753	380	180	11.40	
2-Jun-89	D357	5760	360	210	10.80	
3-Jun-89	D357	5766	380	180	11.40	
4-Jun-89	D358	5774	410	240	12.30	switched
5-Jun-89	D358	5781	435	210	13.05	
6-Jun-89	D358	5790	520	270	15.60	
7-Jun-89	D358	5798	400	240	12.00	
8-Jun-89	D358	5807	610	270	18.30	
9-Jun-89	D358	5814	455	210	13.65	
10-Jun-89	D358	5822	540	240	16.20	
11-Jun-89	D358	5829	480	210	14.40	
12-Jun-89	D358	5833	370	120	11.10	
13-Jun-89	D358	5840	400	210	12.00	
14-Jun-89	D358	5846	400	180	12.00	
15-Jun-89	D358	5852	360	180	10.80	
16-Jun-89	D358	5858	350	180	10.50	
17-Jun-89	D358	5864	340	180	10.20	
18-Jun-89	D358	5872	410	240	12.30	
19-Jun-89	D358	5877	320	150	9.60	
20-Jun-89	D358	5883	370	180	11.10	500 h.service
21-Jun-89	D359	5889	370	180	11.10	
22-Jun-89	D359	5895	440	180	13.20	
23-Jun-89	D359	5902	380	210	11.40	
24-Jun-89	D359	5907	300	150	9.00	
25-Jun-89	D359	5913	360	180	10.80	
26-Jun-89	D359	5920	350	210	10.50	
27-Jun-89	D359	5923	450	90	13.50	
28-Jun-89	D359	5930	370	210	11.10	
29-Jun-89	D359	5937	440	210	13.20	
30-Jun-89	D359	5944	525	210	15.75	
Total				5910	-	2
Average				197	12.28	
Max				270	18.30	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Jul-89	D358	5951	380	210	11.40	outage/switch
2-Jul-89	D357	5957	310	180	9.30	outage/switch
3-Jul-89	D357	5963	320	180	9.60	
4-Jul-89	D357	5969	340	180	10.20	
5-Jul-89	D357	5975	360	180	10.80	
6-Jul-89	D357	5981	360	180	10.80	
7-Jul-89	D357	5987	380	180	11.40	
8-Jul-89	D357	5994	390	210	11.70	
9-Jul-89	D357	6000	350	180	10.50	switched
10-Jul-89	D358	6007	590	210	17.70	
11-Jul-89	D358	6012	600	150	18.00	
12-Jul-89	D358	6021	540	270	16.20	
13-Jul-89	D358	6031	510	300	15.30	
14-Jul-89	D358	6038	480	210	14.40	
15-Jul-89	D358	6045	460	210	13.80	
16-Jul-89	D358	6051	420	180	12.60	
17-Jul-89	D358	6060	490	270	14.70	
18-Jul-89	D358	6065	500	150	15.00	
19-Jul-89	D358	6072	470	210	14.10	
20-Jul-89	D358	6078	465	180	13.95	
21-Jul-89	D358/7	6084	300	180	9.00	service
22-Jul-89	D357	6090	340	180	10.20	
23-Jul-89	D357	6096	400	180	12.00	
24-Jul-89	D357	6102	345	180	10.35	
25-Jul-89	D357	6108	360	180	10.80	
26-Jul-89	D357	6115	440	210	13.20	
27-Jul-89	D357	6118	280	90	8.40	
28-Jul-89	D357	6125	410	210	12.30	
29-Jul-89	D357	6131	410	180	12.30	
30-Jul-89	D357	6136	360	150	10.80	
31-Jul-89	D357	6142	430	180	12.90	
Total				5940	-	4
Average				192	12.38	
Max				300	18.00	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Aug-89	D357	6148	350	180	10.50	
2-Aug-89	D357	6154	430	180	12.90	
3-Aug-89	D357	6160	320	180	9.60	
4-Aug-89	D357	6166	350	180	10.50	
5-Aug-89	D357	6173	390	210	11.70	
6-Aug-89	D357	6180	350	210	10.50	
7-Aug-89	D358	6186	390	180	11.70	switched
8-Aug-89	D358	6194	370	240	11.10	
9-Aug-89	D358	6197	310	90	9.30	
10-Aug-89	D358	6203	370	180	11.10	
11-Aug-89	D358	6210	420	210	12.60	
12-Aug-89	D358	6218	425	240	12.75	
13-Aug-89	D358	6224	415	180	12.45	
14-Aug-89	D358	6230	400	180	12.00	
15-Aug-89	D358	6237	400	210	12.00	
16-Aug-89	D358	6242	280	150	8.40	
17-Aug-89	D358	6248	310	180	9.30	
18-Aug-89	D358	6253	390	150	11.70	
19-Aug-89	D358	6259	330	180	9.90	
20-Aug-89	D358	6266	370	210	11.10	
21-Aug-89	D358/7	6273	380	210	11.40	service/switched
22-Aug-89	D357	6277	490	120	14.70	
23-Aug-89	D357	6286	490	270	14.70	
24-Aug-89	D357	6289	320	90	9.60	
25-Aug-89	D357	6296	420	210	12.60	
26-Aug-89	D357	6302	390	180	11.70	
27-Aug-89	D357	6308	470	180	14.10	
28-Aug-89	D357	6314	410	180	12.30	
29-Aug-89	D357	6322	400	240	12.00	
30-Aug-89	D357	6327	330	150	9.90	
31-Aug-89	D357	6333	420	180	12.60	
Total				5730	-	2
Average				185	11.51	
Max				270	14.70	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Sep-89	D357	6340	430	210	12.90	service/switched
2-Sep-89	D358	6347	350	210	10.50	
3-Sep-89	D358	6353	285	180	8.55	
4-Sep-89	D358	6358	340	150	10.20	
5-Sep-89	D357	6364	295	180	8.85	outage/switch
6-Sep-89	D357	6369	315	150	9.45	
7-Sep-89	D357	6374	350	150	10.50	
8-Sep-89	D357	6380	290	180	8.70	
9-Sep-89	D357	6384	310	120	9.30	switched
10-Sep-89	D358	6390	340	180	10.20	outage/switched
11-Sep-89	D357	6396	310	180	9.30	
12-Sep-89	D357	6401	305	150	9.15	
13-Sep-89	D357	6406	280	150	8.40	
14-Sep-89	D357	6411	340	150	10.20	
15-Sep-89	D357	6417	345	180	10.35	
16-Sep-89	D357	6423	355	180	10.65	
17-Sep-89	D357	6428	355	150	10.65	
18-Sep-89	D357	6434	310	180	9.30	switched
19-Sep-89	D359	6439	290	150	8.70	
20-Sep-89	D359	6444	290	150	8.70	
21-Sep-89	D359	6450	325	180	9.75	
22-Sep-89	D359	6455	320	150	9.60	
23-Sep-89	D359	6458	310	90	9.30	
24-Sep-89	D359	6463	310	150	9.30	
25-Sep-89	D359	6468	250	150	7.50	
26-Sep-89	D359	6473	280	150	8.40	
27-Sep-89	D359	6478	350	150	10.50	
28-Sep-89	D359	6484	405	180	12.15	
29-Sep-89	D359	6491	360	210	10.80	
30-Sep-89	D359	6495	285	120	8.55	Switched
Total				4860	-	6
Average				162	9.68	
Max				210	12.90	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Oct-89	D357	6502	370	210	11.10	
2-Oct-89	D358	6507	370	150	11.10	
3-Oct-89	D358	6512	385	150	11.55	
4-Oct-89	D358	6518	340	180	10.20	
5-Oct-89	D357	6524	340	180	10.20	
6-Oct-89	D357	6530	390	180	11.70	
7-Oct-89	D357	6536	410	180	12.30	
8-Oct-89	D357	6540	360	120	10.80	
9-Oct-89	D357	6545	375	150	11.25	
10-Oct-89	D358	6551	330	180	9.90	
11-Oct-89	D357	6558	430	210	12.90	
12-Oct-89	D357	6564	415	180	12.45	
13-Oct-89	D357	6570	380	180	11.40	service/switch
14-Oct-89	D359	6576	335	180	10.05	
15-Oct-89	D359	6581	325	150	9.75	
16-Oct-89	D359	6587	325	180	9.75	
17-Oct-89	D359	6592	305	150	9.15	
18-Oct-89	D359	6597	320	150	9.60	
19-Oct-89	D359	6602	360	150	10.80	
20-Oct-89	D359	6609	370	210	11.10	
21-Oct-89	D359	6615	435	180	13.05	
22-Oct-89	D359	6618	365	90	10.95	
23-Oct-89	D359	6624	360	180	10.80	
24-Oct-89	D359	6630	370	180	11.10	
25-Oct-89	D359	6636	360	180	10.80	
26-Oct-89	D359	6642	350	180	10.50	
27-Oct-89	D359	6648	400	180	12.00	service/switch
28-Oct-89	D357	6653	280	150	8.40	
29-Oct-89	D357	6659	325	180	9.75	
30-Oct-89	D357	6665	360	180	10.80	
31-Oct-89	D358	6672	475	210	14.25	switch
Total				5310	-	3
Average				171	10.95	
Max				210	14.25	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Nov-89	D358	6679	500	210	15.00	
2-Nov-89	D358	6686	425	210	12.75	
3-Nov-89	D358	6692	470	180	14.10	
4-Nov-89	D358	6701	525	270	15.75	
5-Nov-89	D358	6707	435	180	13.05	service/switch
6-Nov-89	D357	6715	560	240	16.80	
7-Nov-89	D357	6724	460	270	13.80	
8-Nov-89	D357	6728	425	120	12.75	
9-Nov-89	D357	6735	430	210	12.90	
10-Nov-89	D357	6742	500	210	15.00	
11-Nov-89	D357	6748	500	180	15.00	
12-Nov-89	D357	6755	385	210	11.55	
13-Nov-89	D357	6762	385	210	11.55	
14-Nov-89	D357	6768	410	180	12.30	
15-Nov-89	D357	6774	325	180	9.75	
16-Nov-89	D357	6781	415	210	12.45	
17-Nov-89	D357	6787	405	180	12.15	service/switch
18-Nov-89	D359	6793	350	180	10.50	
19-Nov-89	D359	6801	460	240	13.80	
20-Nov-89	D359	6808	405	210	12.15	
21-Nov-89	D359	6815	430	210	12.90	
22-Nov-89	D359	6819	500	120	15.00	
23-Nov-89	D359	6829	605	300	18.15	
24-Nov-89	D359	6837	560	240	16.80	
25-Nov-89	D359	6844	395	210	11.85	
26-Nov-89	D359	6852	410	240	12.30	
27-Nov-89	D359	6858	400	180	12.00	
28-Nov-89	D359	6865	420	210	12.60	
29-Nov-89	D359	6872	480	210	14.40	
30-Nov-89	D359	6880	480	240	14.40	
Total				6240	-	2
Average				208	13.45	
Max				300	18.15	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Dec-89	D359	6887	470	210	14.10	switched
2-Dec-89	D358	6895	470	240	14.10	switched
3-Dec-89	D359	6904	515	270	15.45	switched
4-Dec-89	D359	6913	500	270	15.00	
5-Dec-89	D358	6922	555	270	16.65	switched
6-Dec-89	D358	6930	475	240	14.25	
7-Dec-89	D359	6939	505	270	15.15	switched
8-Dec-89	D359	6943	515	120	15.45	
9-Dec-89	D359	6951	430	240	12.90	
10-Dec-89	D358	6959	525	240	15.75	switched
11-Dec-89	D358	6967	520	240	15.60	
12-Dec-89	D358	6975	525	240	15.75	
13-Dec-89	D358	6984	490	270	14.70	
14-Dec-89	D358	6994	530	300	15.90	
15-Dec-89	D358	7002	505	240	15.15	
16-Dec-89	D358	7011	510	270	15.30	
17-Dec-89	D358	7019	500	240	15.00	
18-Dec-89	D358	7028	415	270	12.45	
19-Dec-89	D358	7038	525	300	15.75	
20-Dec-89	D358	7047	520	270	15.60	
21-Dec-89	D358	7053	555	180	16.65	
22-Dec-89	D358	7062	550	270	16.50	
23-Dec-89	D358	7070	520	240	15.60	
24-Dec-89	D358	7079	495	270	14.85	
25-Dec-89	D358	7088	570	270	17.10	
26-Dec-89	D358	7097	490	270	14.70	service/switch
27-Dec-89	D359	7106	430	270	12.90	
28-Dec-89	D359	7115	530	270	15.90	
29-Dec-89	D359	7123	560	240	16.80	
30-Dec-89	D359	7132	380	270	11.40	
31-Dec-89	D359	7140	460	240	13.80	
Total				7800	-	7
Average				252	15.04	
Max				300	17.10	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Jan-90	D359	7149	475	270	14.25	
2-Jan-90	D359	7158	480	270	14.40	
3-Jan-90	D359	7167	500	270	15.00	
4-Jan-90	D359	7176	530	270	15.90	
5-Jan-90	D359	7186	540	300	16.20	
6-Jan-90	D359	7191	485	150	14.55	
7-Jan-90	D359	7199	460	240	13.80	
8-Jan-90	D359	7208	480	270	14.40	
9-Jan-90	D359	7216	480	240	14.40	
10-Jan-90	D359	7226	590	300	17.70	
11-Jan-90	D359	7233	440	210	13.20	
12-Jan-90	D359	7242	420	270	12.60	
13-Jan-90	D358	7250	500	240	15.00	service/switch
14-Jan-90	D358	7259	480	270	14.40	
15-Jan-90	D358	7268	440	270	13.20	
16-Jan-90	D358	7276	440	240	13.20	
17-Jan-90	D358	7285	425	270	12.75	
18-Jan-90	D358	7294	600	270	18.00	
19-Jan-90	D358	7302	590	240	17.70	
20-Jan-90	D358	7312	550	300	16.50	
21-Jan-90	D358	7318	670	180	20.10	
22-Jan-90	D358	7327	535	270	16.05	
23-Jan-90	D358	7336	530	270	15.90	
24-Jan-90	D358	7345	530	270	15.90	
25-Jan-90	D358	7354	480	270	14.40	
26-Jan-90	D358	7362	480	240	14.40	
27-Jan-90	D358	7370	415	240	12.45	
28-Jan-90	D358	7379	475	270	14.25	
29-Jan-90	D358	7388	490	270	14.70	
30-Jan-90	D358	7396	425	240	12.75	
31-Jan-90	D358	7405	460	270	13.80	
Total				7950	-	1
Average				256	14.90	
Max	-			300	20.10	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Feb-90	D358	7414	500	270	15.00	
2-Feb-90	D358	7422	500	240	15.00	service/switch
3-Feb-90	D359	7430	400	240	12.00	
4-Feb-90	D359	7434	430	120	12.90	
5-Feb-90	D359	7442	470	240	14.10	
6-Feb-90	D359	7449	470	210	14.10	
7-Feb-90	D359	7458	530	270	15.90	
8-Feb-90	D359	7465	460	210	13.80	
9-Feb-90	D359	7474	500	270	15.00	
10-Feb-90	D359	7482	540	240	16.20	
11-Feb-90	D359	7492	580	300	17.40	
12-Feb-90	D359	7500	490	240	14.70	
13-Feb-90	D359	7508	420	240	12.60	
14-Feb-90	D359	7517	500	270	15.00	
15-Feb-90	D359	7525	425	240	12.75	
16-Feb-90	D359	7533	420	240	12.60	
17-Feb-90	D359	7543	580	300	17.40	
18-Feb-90	D359	7550	580	210	17.40	
19-Feb-90	D359	7556.5	580	195	17.40	missing data interpolated
20-Feb-90	D359	7563	580	195	17.40	
21-Feb-90	D359	7571	420	240	12.60	
22-Feb-90	D359	7579	425	240	12.75	
23-Feb-90	D359	7587	470	240	14.10	service/switch
24-Feb-90	D358	7595	480	240	14.40	
25-Feb-90	D358	7604	470	270	14.10	
26-Feb-90	D358	7612	535	240	16.05	
27-Feb-90	D358	7621	555	270	16.65	
28-Feb-90	D358	7630	450	270	13.50	
Total				6750	-	4
Average				241	14.74	
Max				300	17.40	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Mar-90	D358	7639	465	270	13.95	
2-Mar-90	D358	7647	420	240	12.60	
3-Mar-90	D358	7656	485	270	14.55	
4-Mar-90	D358	7665	540	270	16.20	
5-Mar-90	D358	7672	400	210	12.00	
6-Mar-90	D358	7677	420	150	12.60	
7-Mar-90	D358	7685	490	240	14.70	
8-Mar-90	D358	7694	490	270	14.70	
9-Mar-90	D358	7701	410	210	12.30	
10-Mar-90	D358	7708	440	210	13.20	
11-Mar-90	D358	7715	440	210	13.20	
12-Mar-90	D358	7723	440	240	13.20	
13-Mar-90	D358	7730	390	210	11.70	
14-Mar-90	D358	7737	400	210	12.00	
15-Mar-90	D358	7745	430	240	12.90	
16-Mar-90	D358	7753	460	240	13.80	service/switch
17-Mar-90	D359	7759	420	180	12.60	
18-Mar-90	D359	7766	430	210	12.90	
19-Mar-90	D359	7773	400	210	12.00	missing data interpolated
20-Mar-90	D359	7780	370	210	11.10	
21-Mar-90	D359	7783	330	90	9.90	
22-Mar-90	D359	7790	420	210	12.60	
23-Mar-90	D359	7798	430	240	12.90	
24-Mar-90	D359	7805	420	210	12.60	
25-Mar-90	D359	7812	455	210	13.65	
26-Mar-90	D359	7820	450	240	13.50	
27-Mar-90	D359	7828	430	240	12.90	
28-Mar-90	D359	7835	435	210	13.05	
29-Mar-90	D359	7843	500	240	15.00	
30-Mar-90	D359	7853	550	300	16.50	missing data interpolated
31-Mar-90	D359	7863	600	300	18.00	
Total				6990	-	3
Average				225	13.32	
Max				300	18.00	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-Apr-90	D359	7872	600	270	18.00	
2-Apr-90	D359	7880	600	240	18.00	
3-Apr-90	D359	7887	600	210	18.00	
4-Apr-90	D359	7895	440	240	13.20	
5-Apr-90	D359	7904	470	270	14.10	
6-Apr-90	D359	7912	400	240	12.00	
7-Apr-90	D359	7918	420	180	12.60	service/switch
8-Apr-90	D357	7927	485	270	14.55	
9-Apr-90	D357	7936	460	270	13.80	
10-Apr-90	D357	7945	465	270	13.95	
11-Apr-90	D357	7953	450	240	13.50	
12-Apr-90	D357	7963	570	300	17.10	
13-Apr-90	D357	7968	575	150	17.25	
14-Apr-90	D357	7978	540	300	16.20	mechanical
15-Apr-90	D359	7986	400	240	12.00	
16-Apr-90	D359	7993	460	210	13.80	
17-Apr-90	D359	8001	430	240	12.90	
18-Apr-90	D359	8005	435	120	13.05	
19-Apr-90	D359	8013	460	240	13.80	
20-Apr-90	D359	8021	465	240	13.95	
21-Apr-90	D359	8029	410	240	12.30	
22-Apr-90	D359	8036	445	210	13.35	
23-Apr-90	D359	8045	540	270	16.20	
24-Apr-90	D359	8053	400	240	12.00	
25-Apr-90	D359	8060	420	210	12.60	
26-Apr-90	D359	8068	400	240	12.00	
27-Apr-90	D359	8075	430	210	12.90	
28-Apr-90	D359	8083	430	240	12.90	
29-Apr-90	D359	8092	550	270	16.50	
30-Apr-90	D359	8101	520	270	15.60	
Total				7140	-	2
Average				238	14.27	
Max				300	18.00	
Annual Total				**76530**		**38**
Average				**209.67**	**12.89**	**3.17**
Max				**300**	**20.1**	

Cape St James Diesel Records						
Date	Unit#	Watt Hour Rdg	Demand Rdg	kWh past 24 hrs	Peak Demand	Events
1-May-90	D359	8111	540	300	16.20	
2-May-90	D359	8114	530	90	15.90	
3-May-90	D359	8123	590	270	17.70	
4-May-90	D359	8131	405	240	12.15	
5-May-90	D359	8139	450	240	13.50	
6-May-90	D359	8147	410	240	12.30	service/switch
7-May-90	D358	8156	490	270	14.70	
8-May-90	D358	8165	460	270	13.80	
9-May-90	D358	8173	490	240	14.70	
10-May-90	D358	8182	500	270	15.00	
11-May-90	D358	8190	500	240	15.00	
12-May-90	D358	8197	440	210	13.20	
13-May-90	D358	8206	420	270	12.60	outage
14-May-90	D359	8214	415	240	12.45	
15-May-90	D359	8221	390	210	11.70	
16-May-90	D359	8228	480	210	14.40	
17-May-90	D359	8232	440	120	13.20	
18-May-90	D359	8240	490	240	14.70	
19-May-90	D359	8246	390	180	11.70	
20-May-90	D359	8253	390	210	11.70	switched
21-May-90	D358	8260	370	210	11.10	
22-May-90	D358	8267	430	210	12.90	
23-May-90	D358	8274	395	210	11.85	
24-May-90	D358	8281	460	210	13.80	
25-May-90	D358	8288	480	210	14.40	switched
26-May-90	D359	8295	470	210	14.10	
27-May-90	D359	8302	470	210	14.10	
28-May-90	D359	8308	360	180	10.80	
29-May-90	D359	8316	390	240	11.70	
30-May-90	D359	8323	400	210	12.00	
31-May-90	D359	8329	390	180	11.70	
Total				6840	-	4
Average				221	13.39	
Max				300	17.70	

Appendix B

Example Hindcast Analysis Output (November)

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
1-Nov-89 00:00	6.7	2.922	1.253	2.988	41	2.988	10	0.000	0.000	9.597	0.0	5.5	0
1-Nov-89 01:00	7.2	3.574	1.252	3.652	33	3.652	9	22.563	12.000	0.000	9.0	-3.7	1
1-Nov-89 02:00	6.7	2.922	1.252	2.985	47	2.985	9	22.689	12.000	0.000	9.1	-3.7	1
1-Nov-89 03:00	7.2	3.574	1.251	3.650	59	3.650	9	13.550	3.975	0.000	6.4	-1.1	1
1-Nov-89 04:00	8.6	5.222	1.251	5.334	66	1.732	9	11.027	1.732	0.000	5.8	-0.5	1
1-Nov-89 05:00	9.2	5.825	1.252	5.954	69	1.135	9	10.873	1.135	0.000	5.7	-0.4	1
1-Nov-89 06:00	10.3	7.312	1.251	7.469	71	0.861	8	0.000	0.000	8.085	0.0	5.2	0
1-Nov-89 07:00	9.7	6.594	1.250	6.730	62	2.565	8	0.000	0.000	7.791	0.0	5.1	0
1-Nov-89 08:00	9.7	6.594	1.250	6.730	56	5.325	8	0.000	0.000	8.190	0.0	5.2	0
1-Nov-89 09:00	10.8	8.277	1.251	8.452	52	8.090	8	0.000	0.000	8.421	0.0	5.2	0
1-Nov-89 10:00	10.8	8.277	1.251	8.452	49	8.452	8	0.000	0.000	8.001	0.0	5.1	0
1-Nov-89 11:00	10.8	8.277	1.250	8.443	48	8.443	10	0.000	0.000	9.597	0.0	5.5	0
1-Nov-89 12:00	10.8	8.277	1.250	8.449	44	8.449	8	0.000	0.000	8.295	0.0	5.2	0
1-Nov-89 13:00	10.8	8.277	1.249	8.440	43	8.440	8	0.000	0.000	7.707	0.0	5.1	0
1-Nov-89 14:00	9.7	6.594	1.247	6.715	41	6.715	8	0.000	0.000	8.190	0.0	5.2	0
1-Nov-89 15:00	10.3	7.312	1.247	7.444	38	7.444	8	21.534	12.000	0.000	8.7	-3.5	1
1-Nov-89 16:00	11.4	9.090	1.246	9.248	55	6.170	9	16.295	6.170	0.000	7.1	-1.6	1
1-Nov-89 17:00	10.3	7.312	1.247	7.441	65	1.913	9	11.324	1.913	0.000	5.8	-0.6	1
1-Nov-89 18:00	10.8	8.277	1.245	8.415	68	1.272	9	10.549	1.272	0.000	5.7	-0.4	1
1-Nov-89 19:00	11.4	9.090	1.245	9.239	70	0.861	10	0.000	0.000	9.744	0.0	5.5	0
1-Nov-89 20:00	13.3	10.000	1.244	10.153	61	3.373	10	0.000	0.000	9.912	0.0	5.5	0
1-Nov-89 21:00	15.0	9.700	1.242	9.835	53	7.318	9	0.000	0.000	8.862	0.0	5.3	0
1-Nov-89 22:00	15.0	9.700	1.241	9.829	49	9.829	8	0.000	0.000	8.358	0.0	5.2	0
1-Nov-89 23:00	14.4	9.959	1.239	10.073	48	10.073	10	0.000	0.000	9.933	0.0	5.5	0
2-Nov-89 00:00	14.4	9.959	1.238	10.064	46	10.064	10	0.000	0.000	9.597	0.0	5.5	0
2-Nov-89 01:00	12.8	10.000	1.237	10.101	44	10.101	9	0.000	0.000	9.093	0.0	5.4	0
2-Nov-89 02:00	13.3	10.000	1.237	10.101	43	10.101	9	0.000	0.000	9.219	0.0	5.4	0
2-Nov-89 03:00	12.8	10.000	1.237	10.098	41	10.098	9	0.000	0.000	8.883	0.0	5.3	0
2-Nov-89 04:00	11.9	9.829	1.237	9.925	40	9.925	9	0.000	0.000	8.610	0.0	5.3	0
2-Nov-89 05:00	11.4	9.090	1.236	9.173	39	9.173	9	0.000	0.000	9.156	0.0	5.4	0
2-Nov-89 06:00	10.8	8.277	1.234	8.341	37	8.341	8	21.555	12.000	0.000	8.7	-3.5	1
2-Nov-89 07:00	11.4	9.090	1.234	9.161	54	6.170	8	14.594	6.170	0.000	6.6	-1.5	1
2-Nov-89 08:00	10.8	8.277	1.234	8.341	65	2.112	8	11.010	2.112	0.000	5.8	-0.6	1
2-Nov-89 09:00	9.7	6.594	1.235	6.649	68	1.272	8	10.318	1.272	0.000	5.6	-0.4	1
2-Nov-89 10:00	10.3	7.312	1.235	7.374	70	0.861	8	0.000	0.000	8.001	0.0	5.1	0
2-Nov-89 11:00	10.8	8.277	1.236	8.349	62	2.819	10	0.000	0.000	9.597	0.0	5.5	0
2-Nov-89 12:00	9.7	6.594	1.236	6.653	54	6.170	8	0.000	0.000	8.295	0.0	5.2	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
2-Nov-89 13:00	9.2	5.825	1.236	5.879	50	5.879	8	0.000	0.000	7.707	0.0	5.1	0
2-Nov-89 14:00	6.7	2.922	1.237	2.950	47	2.950	8	0.000	0.000	8.190	0.0	5.2	0
2-Nov-89 15:00	10.3	7.312	1.233	7.361	40	7.361	8	0.000	0.000	8.064	0.0	5.2	0
2-Nov-89 16:00	9.7	6.594	1.234	6.643	38	6.643	9	22.962	12.000	0.000	9.2	-3.7	1
2-Nov-89 17:00	9.7	6.594	1.234	6.640	54	6.640	9	16.052	6.691	0.000	7.0	-1.7	1
2-Nov-89 18:00	6.1	2.433	1.235	2.453	65	1.913	9	11.261	1.913	0.000	5.8	-0.6	1
2-Nov-89 19:00	8.6	5.222	1.234	5.263	68	1.272	10	11.641	1.272	0.000	5.9	-0.4	1
2-Nov-89 20:00	10.8	8.277	1.234	8.339	70	0.861	10	0.000	0.000	9.912	0.0	5.5	0
2-Nov-89 21:00	13.3	10.000	1.234	10.071	60	3.373	9	0.000	0.000	8.862	0.0	5.3	0
2-Nov-89 22:00	15.0	9.700	1.234	9.769	53	6.691	8	0.000	0.000	8.358	0.0	5.2	0
2-Nov-89 23:00	12.2	9.988	1.233	10.055	50	10.055	10	0.000	0.000	9.933	0.0	5.5	0
3-Nov-89 00:00	10.8	8.277	1.232	8.327	48	8.327	8	0.000	0.000	8.226	0.0	5.2	0
3-Nov-89 01:00	11.4	9.090	1.232	9.142	46	9.142	8	0.000	0.000	7.794	0.0	5.1	0
3-Nov-89 02:00	10.3	7.312	1.231	7.349	45	7.349	8	0.000	0.000	7.902	0.0	5.1	0
3-Nov-89 03:00	12.8	10.000	1.231	10.051	43	10.051	8	0.000	0.000	7.614	0.0	5.1	0
3-Nov-89 04:00	12.8	10.000	1.229	10.033	43	10.033	7	0.000	0.000	7.380	0.0	5.0	0
3-Nov-89 05:00	13.3	10.000	1.229	10.030	43	10.030	8	0.000	0.000	7.848	0.0	5.1	0
3-Nov-89 06:00	12.8	10.000	1.228	10.026	43	10.026	7	0.000	0.000	6.930	0.0	4.9	0
3-Nov-89 07:00	10.3	7.312	1.227	7.326	44	7.326	7	0.000	0.000	6.678	0.0	4.9	0
3-Nov-89 08:00	10.8	8.277	1.228	8.299	43	8.299	7	0.000	0.000	7.020	0.0	4.9	0
3-Nov-89 09:00	12.2	9.988	1.229	10.018	42	10.018	7	0.000	0.000	7.218	0.0	5.0	0
3-Nov-89 10:00	12.2	9.988	1.229	10.022	43	10.022	7	0.000	0.000	6.858	0.0	4.9	0
3-Nov-89 11:00	12.2	9.988	1.229	10.019	44	10.019	8	0.000	0.000	8.226	0.0	5.2	0
3-Nov-89 12:00	12.2	9.988	1.230	10.026	43	10.026	7	0.000	0.000	7.110	0.0	5.0	0
3-Nov-89 13:00	12.8	10.000	1.230	10.042	44	10.042	7	0.000	0.000	6.606	0.0	4.9	0
3-Nov-89 14:00	13.3	10.000	1.230	10.045	45	10.045	7	0.000	0.000	7.020	0.0	4.9	0
3-Nov-89 15:00	12.2	9.988	1.232	10.045	46	10.045	7	0.000	0.000	6.912	0.0	4.9	0
3-Nov-89 16:00	11.4	9.090	1.227	9.106	47	9.106	8	0.000	0.000	8.136	0.0	5.2	0
3-Nov-89 17:00	15.0	9.700	1.233	9.761	46	9.761	7	0.000	0.000	7.470	0.0	5.0	0
3-Nov-89 18:00	12.8	10.000	1.233	10.067	46	10.067	7	0.000	0.000	7.416	0.0	5.0	0
3-Nov-89 19:00	11.9	9.829	1.234	9.905	47	9.905	8	0.000	0.000	8.352	0.0	5.2	0
3-Nov-89 20:00	14.4	9.959	1.236	10.046	46	10.046	8	0.000	0.000	8.496	0.0	5.2	0
3-Nov-89 21:00	13.9	10.000	1.236	10.092	45	10.092	8	0.000	0.000	7.596	0.0	5.1	0
3-Nov-89 22:00	13.3	10.000	1.237	10.098	45	10.098	7	0.000	0.000	7.164	0.0	5.0	0
3-Nov-89 23:00	12.2	9.988	1.237	10.089	46	10.089	9	0.000	0.000	8.514	0.0	5.2	0
4-Nov-89 00:00	12.8	10.000	1.239	10.112	45	10.112	12	25.809	12.000	0.000	10.2	-4.2	1
4-Nov-89 01:00	12.2	9.988	1.239	10.103	64	2.112	12	14.511	2.112	0.000	6.6	-0.7	1

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
4-Nov-89 02:00	12.2	9.988	1.240	10.110	68	1.415	12	13.904	1.415	0.000	6.5	-0.5	1
4-Nov-89 03:00	13.9	10.000	1.240	10.121	70	0.861	11	12.789	0.861	0.000	6.2	-0.3	1
4-Nov-89 04:00	10.8	8.277	1.241	8.384	72	0.568	11	12.024	0.568	0.000	6.0	-0.2	1
4-Nov-89 05:00	10.8	8.277	1.241	8.384	73	0.414	12	12.482	0.414	0.000	6.1	-0.2	1
4-Nov-89 06:00	10.8	8.277	1.241	8.387	73	0.260	10	10.361	0.260	0.000	5.7	-0.1	1
4-Nov-89 07:00	9.7	6.594	1.241	6.680	74	0.260	10	10.483	0.260	0.000	5.7	-0.1	1
4-Nov-89 08:00	10.3	7.312	1.242	7.416	74	0.116	11	10.742	0.116	0.000	5.7	0.0	1
4-Nov-89 09:00	11.9	9.829	1.242	9.962	74	0.116	11	11.039	0.116	0.000	5.8	0.0	1
4-Nov-89 10:00	9.2	5.825	1.243	5.909	75	0.116	10	10.499	0.116	0.000	5.7	0.0	1
4-Nov-89 11:00	8.6	5.222	1.240	5.285	75	0.000	12	12.339	0.000	0.000	6.1	0.0	1
4-Nov-89 12:00	9.2	5.825	1.238	5.888	75	0.000	11	10.665	0.000	0.000	5.7	0.0	1
4-Nov-89 13:00	9.7	6.594	1.239	6.670	75	0.000	10	0.000	0.000	9.909	0.0	5.5	0
4-Nov-89 14:00	9.2	5.825	1.240	5.897	64	2.329	11	13.580	2.329	0.000	6.4	-0.7	1
4-Nov-89 15:00	8.6	5.222	1.240	5.287	68	1.272	10	12.265	1.272	0.000	6.1	-0.4	1
4-Nov-89 16:00	8.6	5.222	1.240	5.287	70	0.999	12	13.765	0.999	0.000	6.4	-0.4	1
4-Nov-89 17:00	8.3	4.865	1.241	4.929	72	0.568	11	12.159	0.568	0.000	6.0	-0.2	1
4-Nov-89 18:00	9.7	6.594	1.242	6.685	73	0.414	11	11.834	0.414	0.000	6.0	-0.2	1
4-Nov-89 19:00	9.7	6.594	1.242	6.685	73	0.260	13	12.994	0.260	0.000	6.2	-0.1	1
4-Nov-89 20:00	9.7	6.594	1.242	6.683	74	0.260	13	13.210	0.260	0.000	6.3	-0.1	1
4-Nov-89 21:00	11.9	9.829	1.241	9.958	74	0.116	11	11.606	0.116	0.000	5.9	0.0	1
4-Nov-89 22:00	10.8	8.277	1.242	8.389	74	0.116	11	10.958	0.116	0.000	5.8	0.0	1
4-Nov-89 23:00	10.3	7.312	1.244	7.424	75	0.116	13	12.983	0.116	0.000	6.2	-0.1	1
5-Nov-89 00:00	11.9	9.829	1.242	9.969	75	0.000	8	0.000	0.000	8.226	0.0	5.2	0
5-Nov-89 01:00	10.8	8.277	1.241	8.386	66	1.732	8	0.000	0.000	7.794	0.0	5.1	0
5-Nov-89 02:00	10.3	7.312	1.240	7.400	59	3.975	8	0.000	0.000	7.902	0.0	5.1	0
5-Nov-89 03:00	9.2	5.825	1.240	5.897	54	5.897	8	0.000	0.000	7.614	0.0	5.1	0
5-Nov-89 04:00	11.9	9.829	1.239	9.938	50	9.938	7	0.000	0.000	7.380	0.0	5.0	0
5-Nov-89 05:00	12.8	10.000	1.241	10.129	51	10.129	8	0.000	0.000	7.848	0.0	5.1	0
5-Nov-89 06:00	10.3	7.312	1.239	7.396	51	7.396	7	0.000	0.000	6.930	0.0	4.9	0
5-Nov-89 07:00	11.4	9.090	1.239	9.195	49	9.195	7	0.000	0.000	6.678	0.0	4.9	0
5-Nov-89 08:00	10.8	8.277	1.239	8.370	50	8.370	7	0.000	0.000	7.020	0.0	4.9	0
5-Nov-89 09:00	11.9	9.829	1.239	9.939	49	9.939	7	0.000	0.000	7.218	0.0	5.0	0
5-Nov-89 10:00	10.3	7.312	1.239	7.394	50	7.394	7	0.000	0.000	6.858	0.0	4.9	0
5-Nov-89 11:00	12.2	9.988	1.241	10.121	48	10.121	8	0.000	0.000	8.226	0.0	5.2	0
5-Nov-89 12:00	11.9	9.829	1.238	9.935	48	9.935	7	0.000	0.000	7.110	0.0	5.0	0
5-Nov-89 13:00	10.3	7.312	1.234	7.365	49	7.365	7	0.000	0.000	6.606	0.0	4.9	0
5-Nov-89 14:00	10.3	7.312	1.239	7.394	48	7.394	7	0.000	0.000	7.020	0.0	4.9	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
5-Nov-89 15:00	5.6	1.919	1.244	1.948	46	1.948	7	0.000	0.000	6.912	0.0	4.9	0
5-Nov-89 16:00	9.2	5.825	1.240	5.896	40	5.896	8	0.000	0.000	8.136	0.0	5.2	0
5-Nov-89 17:00	8.6	5.222	1.240	5.286	36	5.286	7	20.940	12.000	0.000	8.5	-3.4	1
5-Nov-89 18:00	8.3	4.865	1.240	4.927	51	4.927	7	17.337	9.058	0.000	7.4	-2.4	1
5-Nov-89 19:00	8.3	4.865	1.240	4.924	63	2.565	8	11.651	2.565	0.000	5.9	-0.7	1
5-Nov-89 20:00	10.3	7.312	1.241	7.410	67	1.415	8	10.547	1.415	0.000	5.7	-0.4	1
5-Nov-89 21:00	9.2	5.825	1.239	5.893	70	0.999	8	0.000	0.000	7.596	0.0	5.1	0
5-Nov-89 22:00	6.7	2.922	1.240	2.958	62	2.819	7	0.000	0.000	7.164	0.0	5.0	0
5-Nov-89 23:00	5.6	1.919	1.241	1.944	57	1.944	9	0.000	0.000	8.514	0.0	5.2	0
6-Nov-89 00:00	6.1	2.433	1.239	2.460	49	2.460	11	24.438	12.000	0.000	9.7	-3.9	1
6-Nov-89 01:00	8.6	5.222	1.237	5.271	61	3.089	10	14.214	3.089	0.000	6.5	-0.9	1
6-Nov-89 02:00	9.7	6.594	1.234	6.642	67	1.567	11	12.777	1.567	0.000	6.2	-0.5	1
6-Nov-89 03:00	9.2	5.825	1.233	5.862	69	0.999	10	11.713	0.999	0.000	5.9	-0.3	1
6-Nov-89 04:00	8.6	5.222	1.231	5.250	71	0.718	10	0.000	0.000	9.840	0.0	5.5	0
6-Nov-89 05:00	11.9	9.829	1.225	9.829	61	3.089	10	14.286	3.089	0.000	6.6	-0.9	1
6-Nov-89 06:00	18.6	3.483	1.225	3.484	66	1.732	9	11.657	1.732	0.000	5.9	-0.5	1
6-Nov-89 07:00	18.1	3.409	1.226	3.412	69	1.135	9	10.621	1.135	0.000	5.7	-0.4	1
6-Nov-89 08:00	16.4	3.290	1.228	3.299	71	0.718	9	0.000	0.000	9.360	0.0	5.4	0
6-Nov-89 09:00	17.5	3.346	1.228	3.353	61	3.089	10	0.000	0.000	9.624	0.0	5.5	0
6-Nov-89 10:00	15.8	6.096	1.229	6.118	53	6.118	9	0.000	0.000	9.144	0.0	5.4	0
6-Nov-89 11:00	21.7	3.819	1.229	3.832	49	3.832	11	24.438	12.000	0.000	9.7	-3.9	1
6-Nov-89 12:00	17.5	3.346	1.234	3.372	62	2.819	9	13.019	2.819	0.000	6.2	-0.8	1
6-Nov-89 13:00	18.1	3.409	1.230	3.424	67	1.567	9	11.049	1.567	0.000	5.8	-0.5	1
6-Nov-89 14:00	16.4	3.290	1.230	3.305	70	0.999	9	0.000	0.000	9.360	0.0	5.4	0
6-Nov-89 15:00	15.6	8.200	1.240	8.298	60	3.373	9	0.000	0.000	9.216	0.0	5.4	0
6-Nov-89 16:00	13.3	10.000	1.236	10.093	53	7.318	11	18.839	7.318	0.000	7.8	-2.1	1
6-Nov-89 17:00	23.1	3.960	1.240	4.007	65	1.913	10	12.569	1.913	0.000	6.1	-0.6	1
6-Nov-89 18:00	15.0	9.700	1.240	9.818	69	1.135	10	11.605	1.135	0.000	5.9	-0.4	1
6-Nov-89 19:00	15.6	8.200	1.244	8.326	71	0.861	11	12.504	0.861	0.000	6.1	-0.3	1
6-Nov-89 20:00	9.7	6.594	1.247	6.712	72	0.568	11	12.282	0.568	0.000	6.1	-0.2	1
6-Nov-89 21:00	16.4	3.290	1.241	3.332	73	0.414	10	10.838	0.414	0.000	5.7	-0.2	1
6-Nov-89 22:00	15.8	6.096	1.241	6.174	74	0.260	10	0.000	0.000	9.552	0.0	5.5	0
6-Nov-89 23:00	12.2	9.988	1.242	10.123	63	2.329	11	14.402	2.329	0.000	6.6	-0.7	1
7-Nov-89 00:00	12.8	10.000	1.242	10.139	67	1.415	12	14.390	1.415	0.000	6.6	-0.5	1
7-Nov-89 01:00	13.3	10.000	1.244	10.157	70	0.999	12	13.252	0.999	0.000	6.3	-0.4	1
7-Nov-89 02:00	9.2	5.825	1.247	5.929	72	0.718	12	13.013	0.718	0.000	6.2	-0.3	1
7-Nov-89 03:00	15.6	8.200	1.242	8.311	73	0.414	11	12.131	0.414	0.000	6.0	-0.2	1

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
7-Nov-89 04:00	15.8	6.096	1.242	6.181	73	0.260	11	11.536	0.260	0.000	5.9	-0.1	1
7-Nov-89 05:00	14.4	9.959	1.240	10.083	74	0.260	12	12.238	0.260	0.000	6.1	-0.1	1
7-Nov-89 06:00	12.8	10.000	1.240	10.125	74	0.116	10	10.607	0.116	0.000	5.7	0.0	1
7-Nov-89 07:00	12.8	10.000	1.245	10.163	75	0.116	10	10.229	0.116	0.000	5.6	0.0	1
7-Nov-89 08:00	11.4	9.090	1.241	9.206	75	0.000	11	10.530	0.000	0.000	5.7	0.0	1
7-Nov-89 09:00	7.2	3.574	1.240	3.619	75	0.000	11	10.827	0.000	0.000	5.7	0.0	1
7-Nov-89 10:00	9.7	6.594	1.238	6.661	75	0.000	10	10.287	0.000	0.000	5.6	0.0	1
7-Nov-89 11:00	8.6	5.222	1.238	5.276	75	0.000	12	12.339	0.000	0.000	6.1	0.0	1
7-Nov-89 12:00	10.3	7.312	1.238	7.387	75	0.000	11	10.665	0.000	0.000	5.7	0.0	1
7-Nov-89 13:00	13.9	10.000	1.235	10.082	75	0.000	10	0.000	0.000	9.909	0.0	5.5	0
7-Nov-89 14:00	16.4	3.290	1.231	3.307	64	2.329	11	13.580	2.329	0.000	6.4	-0.7	1
7-Nov-89 15:00	18.1	3.409	1.229	3.419	68	1.272	10	12.265	1.272	0.000	6.1	-0.4	1
7-Nov-89 16:00	19.2	3.543	1.226	3.546	70	0.999	12	13.765	0.999	0.000	6.4	-0.4	1
7-Nov-89 17:00	20.0	3.646	1.223	3.640	72	0.568	11	12.159	0.568	0.000	6.0	-0.2	1
7-Nov-89 18:00	20.6	3.701	1.221	3.688	73	0.414	11	11.834	0.414	0.000	6.0	-0.2	1
7-Nov-89 19:00	22.2	3.880	1.219	3.863	73	0.260	13	12.994	0.260	0.000	6.2	-0.1	1
7-Nov-89 20:00	21.1	3.766	1.219	3.748	74	0.260	13	13.210	0.260	0.000	6.3	-0.1	1
7-Nov-89 21:00	23.1	3.960	1.216	3.929	74	0.116	11	11.606	0.116	0.000	5.9	0.0	1
7-Nov-89 22:00	22.2	3.880	1.215	3.849	74	0.116	11	10.958	0.116	0.000	5.8	0.0	1
7-Nov-89 23:00	23.6	4.018	1.213	3.979	75	0.116	13	12.983	0.116	0.000	6.2	-0.1	1
8-Nov-89 00:00	25.8	4.218	1.216	4.187	75	0.000	5	0.000	0.000	5.484	0.0	4.7	0
8-Nov-89 01:00	21.1	3.766	1.222	3.757	69	1.135	5	0.000	0.000	5.196	0.0	4.6	0
8-Nov-89 02:00	20.0	3.646	1.222	3.636	64	2.112	5	0.000	0.000	5.268	0.0	4.6	0
8-Nov-89 03:00	16.9	3.268	1.226	3.270	60	3.270	5	0.000	0.000	5.076	0.0	4.6	0
8-Nov-89 04:00	13.3	10.000	1.227	10.018	57	4.618	5	0.000	0.000	4.920	0.0	4.6	0
8-Nov-89 05:00	12.2	9.988	1.229	10.023	55	5.722	5	0.000	0.000	5.232	0.0	4.6	0
8-Nov-89 06:00	12.2	9.988	1.229	10.023	54	6.170	5	0.000	0.000	4.620	0.0	4.5	0
8-Nov-89 07:00	10.3	7.312	1.230	7.342	55	6.170	4	0.000	0.000	4.452	0.0	4.5	0
8-Nov-89 08:00	8.3	4.865	1.231	4.890	55	4.890	5	0.000	0.000	4.680	0.0	4.5	0
8-Nov-89 09:00	5.6	1.919	1.233	1.932	54	1.932	5	0.000	0.000	4.812	0.0	4.5	0
8-Nov-89 10:00	8.3	4.865	1.235	4.906	50	4.906	5	0.000	0.000	4.572	0.0	4.5	0
8-Nov-89 11:00	7.2	3.574	1.233	3.596	49	3.596	5	0.000	0.000	5.484	0.0	4.7	0
8-Nov-89 12:00	5.3	1.691	1.232	1.701	46	1.701	5	0.000	0.000	4.740	0.0	4.5	0
8-Nov-89 13:00	6.7	2.922	1.232	2.939	42	2.939	4	0.000	0.000	4.404	0.0	4.5	0
8-Nov-89 14:00	4.2	1.008	1.235	1.015	40	1.015	5	0.000	0.000	4.680	0.0	4.5	0
8-Nov-89 15:00	4.2	1.008	1.235	1.016	35	1.016	5	18.078	12.000	0.000	7.6	-3.1	1
8-Nov-89 16:00	3.1	0.000	1.235	0.000	46	0.000	5	18.894	12.000	0.000	7.8	-3.2	1

Appendix B

Battery capacity=	77.000	kWh	Month:	November, 1989
Diesel capacity=	30.000	kW		
Wind turbine capacity=	10.000	kW		actual loads
Inverter capacity=	20.000	kW		

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
8-Nov-89 17:00	3.6	0.667	1.237	0.673	57	0.673	5	10.588	4.961	0.000	5.7	-1.1	1
8-Nov-89 18:00	5.3	1.691	1.235	1.706	61	1.706	5	8.766	3.089	0.000	5.3	-0.7	1
8-Nov-89 19:00	5.3	1.691	1.237	1.708	66	1.708	6	7.985	1.732	0.000	5.1	-0.5	1
8-Nov-89 20:00	6.1	2.433	1.229	2.441	68	1.272	6	7.561	1.272	0.000	5.1	-0.4	1
8-Nov-89 21:00	6.1	2.433	1.222	2.426	71	0.861	5	0.000	0.000	5.064	0.0	4.6	0
8-Nov-89 22:00	4.2	1.008	1.219	1.003	66	1.003	5	0.000	0.000	4.776	0.0	4.5	0
8-Nov-89 23:00	18.1	3.409	1.207	3.359	61	3.089	6	0.000	0.000	5.676	0.0	4.7	0
9-Nov-89 00:00	19.2	3.543	1.206	3.489	58	3.489	10	0.000	0.000	9.597	0.0	5.5	0
9-Nov-89 01:00	18.1	3.409	1.206	3.355	50	3.355	9	0.000	0.000	9.093	0.0	5.4	0
9-Nov-89 02:00	20.6	3.701	1.205	3.640	43	3.640	9	0.000	0.000	9.219	0.0	5.4	0
9-Nov-89 03:00	21.1	3.766	1.203	3.700	36	3.700	9	22.353	12.000	0.000	9.0	-3.6	1
9-Nov-89 04:00	20.6	3.701	1.204	3.637	49	3.637	9	22.080	12.000	0.000	8.9	-3.6	1
9-Nov-89 05:00	19.2	3.543	1.204	3.481	63	2.565	9	12.455	2.565	0.000	6.1	-0.7	1
9-Nov-89 06:00	18.6	3.483	1.205	3.426	67	1.567	8	10.326	1.567	0.000	5.6	-0.5	1
9-Nov-89 07:00	16.9	3.268	1.205	3.215	70	0.999	8	0.000	0.000	7.791	0.0	5.1	0
9-Nov-89 08:00	17.5	3.346	1.206	3.294	62	2.819	8	0.000	0.000	8.190	0.0	5.2	0
9-Nov-89 09:00	16.4	3.290	1.207	3.242	55	3.242	8	0.000	0.000	8.421	0.0	5.2	0
9-Nov-89 10:00	16.9	3.268	1.208	3.221	49	3.221	8	0.000	0.000	8.001	0.0	5.1	0
9-Nov-89 11:00	15.0	9.700	1.209	9.573	43	9.573	10	0.000	0.000	9.597	0.0	5.5	0
9-Nov-89 12:00	15.0	9.700	1.209	9.576	40	9.576	8	0.000	0.000	8.295	0.0	5.2	0
9-Nov-89 13:00	16.9	3.268	1.208	3.224	40	3.224	8	0.000	0.000	7.707	0.0	5.1	0
9-Nov-89 14:00	16.9	3.268	1.209	3.225	34	3.225	8	21.660	12.000	0.000	8.7	-3.5	1
9-Nov-89 15:00	12.8	10.000	1.223	9.980	47	9.980	8	21.534	12.000	0.000	8.7	-3.5	1
9-Nov-89 16:00	12.2	9.988	1.226	9.996	65	1.732	9	11.909	1.732	0.000	6.0	-0.5	1
9-Nov-89 17:00	16.4	3.290	1.233	3.312	68	1.272	9	10.612	1.272	0.000	5.7	-0.4	1
9-Nov-89 18:00	14.4	9.959	1.238	10.065	71	0.861	9	0.000	0.000	8.652	0.0	5.3	0
9-Nov-89 19:00	15.0	9.700	1.241	9.830	62	2.819	10	0.000	0.000	9.744	0.0	5.5	0
9-Nov-89 20:00	16.4	3.290	1.243	3.338	54	3.338	10	0.000	0.000	9.912	0.0	5.5	0
9-Nov-89 21:00	14.4	9.959	1.243	10.109	46	10.109	9	0.000	0.000	8.862	0.0	5.3	0
9-Nov-89 22:00	16.4	3.290	1.245	3.343	44	3.343	8	0.000	0.000	8.358	0.0	5.2	0
9-Nov-89 23:00	13.9	10.000	1.248	10.185	38	10.185	10	23.403	12.000	0.000	9.3	-3.8	1
10-Nov-89 00:00	12.2	9.988	1.251	10.198	57	4.961	10	15.205	4.961	0.000	6.8	-1.3	1
10-Nov-89 01:00	10.3	7.312	1.254	7.483	65	1.913	9	11.702	1.913	0.000	5.9	-0.6	1
10-Nov-89 02:00	12.8	10.000	1.253	10.231	69	1.135	9	10.936	1.135	0.000	5.8	-0.4	1
10-Nov-89 03:00	12.8	10.000	1.252	10.219	71	0.861	9	0.000	0.000	8.883	0.0	5.3	0
10-Nov-89 04:00	9.7	6.594	1.254	6.750	62	3.089	9	0.000	0.000	8.610	0.0	5.3	0
10-Nov-89 05:00	9.7	6.594	1.253	6.745	55	5.722	9	0.000	0.000	9.156	0.0	5.4	0

Appendix B

Battery capacity=	77.000	kWh	Month:	November, 1989
Diesel capacity=	30.000	kW		
Wind turbine capacity=	10.000	kW		actual loads
Inverter capacity=	20.000	kW		

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
10-Nov-89 06:00	7.8	4.153	1.252	4.246	50	4.246	8	0.000	0.000	8.085	0.0	5.2	0
10-Nov-89 07:00	10.8	8.277	1.255	8.482	44	8.482	8	0.000	0.000	7.791	0.0	5.1	0
10-Nov-89 08:00	8.3	4.865	1.258	4.998	43	4.998	8	0.000	0.000	8.190	0.0	5.2	0
10-Nov-89 09:00	6.7	2.922	1.255	2.994	38	2.994	8	21.891	12.000	0.000	8.8	-3.6	1
10-Nov-89 10:00	7.2	3.574	1.261	3.679	51	3.679	8	17.922	9.058	0.000	7.5	-2.4	1
10-Nov-89 11:00	7.8	4.153	1.257	4.262	62	2.819	10	13.136	2.819	0.000	6.3	-0.8	1
10-Nov-89 12:00	6.7	2.922	1.259	3.003	67	1.567	8	10.536	1.567	0.000	5.7	-0.5	1
10-Nov-89 13:00	9.2	5.825	1.252	5.955	69	0.999	8	0.000	0.000	7.707	0.0	5.1	0
10-Nov-89 14:00	10.3	7.312	1.249	7.457	62	2.819	8	0.000	0.000	8.190	0.0	5.2	0
10-Nov-89 15:00	9.7	6.594	1.253	6.742	55	5.722	8	0.000	0.000	8.064	0.0	5.2	0
10-Nov-89 16:00	10.3	7.312	1.254	7.487	51	7.487	9	0.000	0.000	9.492	0.0	5.4	0
10-Nov-89 17:00	8.6	5.222	1.264	5.387	47	5.387	9	0.000	0.000	8.715	0.0	5.3	0
10-Nov-89 18:00	6.7	2.922	1.265	3.018	42	3.018	9	0.000	0.000	8.652	0.0	5.3	0
10-Nov-89 19:00	4.2	1.008	1.267	1.042	35	1.042	10	23.214	12.000	0.000	9.3	-3.8	1
10-Nov-89 20:00	1.9	0.000	1.269	0.000	46	0.000	10	23.382	12.000	0.000	9.3	-3.8	1
10-Nov-89 21:00	1.9	0.000	1.267	0.000	57	0.000	9	14.470	4.961	0.000	6.6	-1.3	1
10-Nov-89 22:00	7.8	4.153	1.264	4.287	61	3.089	8	12.180	3.089	0.000	6.0	-0.8	1
10-Nov-89 23:00	7.2	3.574	1.266	3.694	66	1.732	10	12.350	1.732	0.000	6.1	-0.5	1
11-Nov-89 00:00	4.2	1.008	1.269	1.044	69	1.044	8	9.943	1.135	0.000	5.5	-0.4	1
11-Nov-89 01:00	2.5	0.000	1.272	0.000	71	0.000	8	0.000	0.000	7.794	0.0	5.1	0
11-Nov-89 02:00	2.5	0.000	1.273	0.000	62	0.000	8	0.000	0.000	7.902	0.0	5.1	0
11-Nov-89 03:00	1.9	0.000	1.275	0.000	54	0.000	8	0.000	0.000	7.614	0.0	5.1	0
11-Nov-89 04:00	2.5	0.000	1.277	0.000	45	0.000	7	0.000	0.000	7.380	0.0	5.0	0
11-Nov-89 05:00	0.6	0.000	1.272	0.000	37	0.000	8	21.318	12.000	0.000	8.6	-3.5	1
11-Nov-89 06:00	1.1	0.000	1.274	0.000	48	0.000	7	20.400	12.000	0.000	8.3	-3.4	1
11-Nov-89 07:00	1.7	0.000	1.272	0.000	58	0.000	7	11.650	4.291	0.000	5.9	-1.0	1
11-Nov-89 08:00	1.9	0.000	1.280	0.000	61	0.000	7	10.842	3.089	0.000	5.7	-0.8	1
11-Nov-89 09:00	0.6	0.000	1.274	0.000	64	0.000	7	10.038	2.112	0.000	5.6	-0.6	1
11-Nov-89 10:00	2.5	0.000	1.270	0.000	66	0.000	7	9.275	1.732	0.000	5.4	-0.5	1
11-Nov-89 11:00	10.8	8.277	1.266	8.553	67	1.415	8	10.277	1.415	0.000	5.6	-0.4	1
11-Nov-89 12:00	5.6	1.919	1.259	1.972	70	0.999	7	0.000	0.000	7.110	0.0	5.0	0
11-Nov-89 13:00	5.3	1.691	1.269	1.752	63	1.752	7	0.000	0.000	6.606	0.0	4.9	0
11-Nov-89 14:00	7.8	4.153	1.256	4.259	57	4.259	7	0.000	0.000	7.020	0.0	4.9	0
11-Nov-89 15:00	7.2	3.574	1.264	3.687	53	3.687	7	0.000	0.000	6.912	0.0	4.9	0
11-Nov-89 16:00	4.7	1.355	1.264	1.398	48	1.398	8	0.000	0.000	8.136	0.0	5.2	0
11-Nov-89 17:00	8.3	4.865	1.263	5.018	41	5.018	7	0.000	0.000	7.470	0.0	5.0	0
11-Nov-89 18:00	5.3	1.691	1.270	1.753	37	1.753	7	20.886	12.000	0.000	8.5	-3.4	1

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
11-Nov-89 19:00	4.2	1.008	1.268	1.043	49	1.043	8	21.822	12.000	0.000	8.8	-3.6	1
11-Nov-89 20:00	3.1	0.000	1.271	0.000	60	0.000	8	12.870	3.668	0.000	6.2	-1.0	1
11-Nov-89 21:00	1.7	0.000	1.273	0.000	63	0.000	8	10.895	2.565	0.000	5.7	-0.7	1
11-Nov-89 22:00	10.8	8.277	1.270	8.582	65	1.913	7	9.773	1.913	0.000	5.5	-0.5	1
11-Nov-89 23:00	1.7	0.000	1.271	0.000	68	0.000	9	10.411	1.272	0.000	5.6	-0.4	1
12-Nov-89 00:00	5.6	1.919	1.263	1.979	69	1.135	10	11.314	1.135	0.000	5.8	-0.4	1
12-Nov-89 01:00	9.7	6.594	1.258	6.773	71	0.718	9	0.000	0.000	9.093	0.0	5.4	0
12-Nov-89 02:00	8.3	4.865	1.262	5.013	62	2.819	9	0.000	0.000	9.219	0.0	5.4	0
12-Nov-89 03:00	8.6	5.222	1.263	5.384	54	5.384	9	0.000	0.000	8.883	0.0	5.3	0
12-Nov-89 04:00	5.3	1.691	1.262	1.742	49	1.742	9	0.000	0.000	8.610	0.0	5.3	0
12-Nov-89 05:00	4.7	1.355	1.259	1.393	41	1.393	9	0.000	0.000	9.156	0.0	5.4	0
12-Nov-89 06:00	5.3	1.691	1.258	1.736	32	1.736	8	21.555	12.000	0.000	8.7	-3.5	1
12-Nov-89 07:00	4.7	1.355	1.258	1.392	44	1.392	8	21.261	12.000	0.000	8.6	-3.5	1
12-Nov-89 08:00	4.7	1.355	1.260	1.394	55	1.394	8	14.539	5.722	0.000	6.6	-1.4	1
12-Nov-89 09:00	6.7	2.922	1.263	3.012	61	3.012	8	12.243	3.089	0.000	6.1	-0.8	1
12-Nov-89 10:00	8.3	4.865	1.256	4.987	66	1.567	8	10.242	1.567	0.000	5.6	-0.5	1
12-Nov-89 11:00	13.3	10.000	1.247	10.181	69	1.135	10	11.314	1.135	0.000	5.8	-0.4	1
12-Nov-89 12:00	9.2	5.825	1.254	5.962	71	0.718	8	0.000	0.000	8.295	0.0	5.2	0
12-Nov-89 13:00	12.2	9.988	1.251	10.199	63	2.565	8	0.000	0.000	7.707	0.0	5.1	0
12-Nov-89 14:00	11.9	9.829	1.246	9.998	56	4.961	8	0.000	0.000	8.190	0.0	5.2	0
12-Nov-89 15:00	12.8	10.000	1.242	10.141	52	8.090	8	0.000	0.000	8.064	0.0	5.2	0
12-Nov-89 16:00	12.8	10.000	1.240	10.120	50	10.120	9	0.000	0.000	9.492	0.0	5.4	0
12-Nov-89 17:00	16.4	3.290	1.235	3.316	48	3.316	9	0.000	0.000	8.715	0.0	5.3	0
12-Nov-89 18:00	10.3	7.312	1.238	7.388	41	7.388	9	0.000	0.000	8.652	0.0	5.3	0
12-Nov-89 19:00	10.3	7.312	1.233	7.363	38	7.363	10	23.214	12.000	0.000	9.3	-3.8	1
12-Nov-89 20:00	9.2	5.825	1.233	5.865	54	5.865	10	16.715	6.170	0.000	7.2	-1.7	1
12-Nov-89 21:00	15.8	6.096	1.233	6.135	65	2.112	9	11.682	2.112	0.000	5.9	-0.6	1
12-Nov-89 22:00	11.9	9.829	1.232	9.886	68	1.272	8	10.255	1.272	0.000	5.6	-0.4	1
12-Nov-89 23:00	10.3	7.312	1.232	7.352	70	0.861	10	0.000	0.000	9.933	0.0	5.5	0
13-Nov-89 00:00	12.8	10.000	1.233	10.062	60	3.373	10	0.000	0.000	9.597	0.0	5.5	0
13-Nov-89 01:00	9.2	5.825	1.235	5.873	53	5.873	9	0.000	0.000	9.093	0.0	5.4	0
13-Nov-89 02:00	11.9	9.829	1.229	9.862	48	9.862	9	0.000	0.000	9.219	0.0	5.4	0
13-Nov-89 03:00	15.0	9.700	1.229	9.733	46	9.733	9	0.000	0.000	8.883	0.0	5.3	0
13-Nov-89 04:00	14.4	9.959	1.226	9.971	44	9.971	9	0.000	0.000	8.610	0.0	5.3	0
13-Nov-89 05:00	15.0	9.700	1.229	9.733	44	9.733	9	0.000	0.000	9.156	0.0	5.4	0
13-Nov-89 06:00	14.4	9.959	1.230	10.003	42	10.003	8	0.000	0.000	8.085	0.0	5.2	0
13-Nov-89 07:00	15.6	8.200	1.231	8.239	41	8.239	8	0.000	0.000	7.791	0.0	5.1	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
13-Nov-89 08:00	10.3	7.312	1.240	7.399	40	7.399	8	0.000	0.000	8.190	0.0	5.2	0
13-Nov-89 09:00	12.8	10.000	1.235	10.078	37	10.078	8	21.891	12.000	0.000	8.8	-3.6	1
13-Nov-89 10:00	12.8	10.000	1.231	10.049	56	5.325	8	13.958	5.325	0.000	6.5	-1.3	1
13-Nov-89 11:00	15.0	9.700	1.230	9.736	65	1.913	10	12.206	1.913	0.000	6.0	-0.6	1
13-Nov-89 12:00	19.2	3.543	1.236	3.574	68	1.272	8	10.192	1.272	0.000	5.6	-0.4	1
13-Nov-89 13:00	19.2	3.543	1.239	3.583	70	0.861	8	0.000	0.000	7.707	0.0	5.1	0
13-Nov-89 14:00	22.2	3.880	1.242	3.934	63	2.565	8	0.000	0.000	8.190	0.0	5.2	0
13-Nov-89 15:00	20.6	3.701	1.246	3.764	56	3.764	8	0.000	0.000	8.064	0.0	5.2	0
13-Nov-89 16:00	18.1	3.409	1.249	3.477	50	3.477	9	0.000	0.000	9.492	0.0	5.4	0
13-Nov-89 17:00	17.5	3.346	1.256	3.431	43	3.431	9	0.000	0.000	8.715	0.0	5.3	0
13-Nov-89 18:00	17.5	3.346	1.261	3.443	36	3.443	9	22.122	12.000	0.000	8.9	-3.6	1
13-Nov-89 19:00	12.8	10.000	1.260	10.286	49	10.286	10	22.126	11.120	0.000	8.9	-3.4	1
13-Nov-89 20:00	10.3	7.312	1.263	7.538	68	1.415	10	11.963	1.415	0.000	6.0	-0.5	1
13-Nov-89 21:00	7.8	4.153	1.267	4.295	70	0.999	9	0.000	0.000	8.862	0.0	5.3	0
13-Nov-89 22:00	6.7	2.922	1.268	3.024	61	3.024	8	0.000	0.000	8.358	0.0	5.2	0
13-Nov-89 23:00	5.3	1.691	1.269	1.752	55	1.752	10	0.000	0.000	9.933	0.0	5.5	0
14-Nov-89 00:00	4.7	1.355	1.270	1.405	45	1.405	8	0.000	0.000	8.226	0.0	5.2	0
14-Nov-89 01:00	6.7	2.922	1.275	3.040	37	3.040	8	21.264	12.000	0.000	8.6	-3.5	1
14-Nov-89 02:00	4.2	1.008	1.276	1.049	50	1.049	8	19.265	10.286	0.000	7.9	-2.8	1
14-Nov-89 03:00	4.2	1.008	1.277	1.050	60	1.050	8	11.988	3.668	0.000	6.0	-0.9	1
14-Nov-89 04:00	3.1	0.000	1.276	0.000	64	0.000	7	10.430	2.329	0.000	5.6	-0.6	1
14-Nov-89 05:00	2.5	0.000	1.280	0.000	66	0.000	8	10.265	1.732	0.000	5.6	-0.5	1
14-Nov-89 06:00	2.5	0.000	1.277	0.000	67	0.000	7	8.981	1.415	0.000	5.3	-0.4	1
14-Nov-89 07:00	1.9	0.000	1.278	0.000	68	0.000	7	8.575	1.272	0.000	5.3	-0.4	1
14-Nov-89 08:00	1.1	0.000	1.279	0.000	70	0.000	7	0.000	0.000	7.020	0.0	4.9	0
14-Nov-89 09:00	1.1	0.000	1.278	0.000	62	0.000	7	0.000	0.000	7.218	0.0	5.0	0
14-Nov-89 10:00	1.1	0.000	1.277	0.000	54	0.000	7	0.000	0.000	6.858	0.0	4.9	0
14-Nov-89 11:00	1.1	0.000	1.276	0.000	46	0.000	8	0.000	0.000	8.226	0.0	5.2	0
14-Nov-89 12:00	1.1	0.000	1.274	0.000	37	0.000	7	20.580	12.000	0.000	8.4	-3.4	1
14-Nov-89 13:00	2.5	0.000	1.272	0.000	48	0.000	7	20.076	12.000	0.000	8.2	-3.3	1
14-Nov-89 14:00	4.7	1.355	1.271	1.406	58	1.406	7	11.992	4.291	0.000	6.0	-1.0	1
14-Nov-89 15:00	5.6	1.919	1.271	1.991	63	1.991	7	10.211	2.565	0.000	5.6	-0.7	1
14-Nov-89 16:00	6.1	2.433	1.272	2.525	67	1.567	8	10.377	1.567	0.000	5.6	-0.5	1
14-Nov-89 17:00	6.7	2.922	1.271	3.031	69	1.135	7	9.187	1.135	0.000	5.4	-0.3	1
14-Nov-89 18:00	6.7	2.922	1.269	3.028	71	0.718	7	0.000	0.000	7.416	0.0	5.0	0
14-Nov-89 19:00	7.2	3.574	1.269	3.701	64	2.329	8	0.000	0.000	8.352	0.0	5.2	0
14-Nov-89 20:00	8.3	4.865	1.271	5.046	56	4.961	8	0.000	0.000	8.496	0.0	5.2	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
14-Nov-89 21:00	10.8	8.277	1.274	8.607	51	8.607	8	0.000	0.000	7.596	0.0	5.1	0
14-Nov-89 22:00	10.3	7.312	1.275	7.609	50	7.609	7	0.000	0.000	7.164	0.0	5.0	0
14-Nov-89 23:00	11.4	9.090	1.272	9.440	49	9.440	9	0.000	0.000	8.514	0.0	5.2	0
15-Nov-89 00:00	14.4	9.959	1.270	10.325	48	10.325	8	0.000	0.000	8.226	0.0	5.2	0
15-Nov-89 01:00	12.8	10.000	1.267	10.346	47	10.346	8	0.000	0.000	7.794	0.0	5.1	0
15-Nov-89 02:00	16.4	3.290	1.262	3.388	48	3.388	8	0.000	0.000	7.902	0.0	5.1	0
15-Nov-89 03:00	15.6	8.200	1.256	8.404	42	8.404	8	0.000	0.000	7.614	0.0	5.1	0
15-Nov-89 04:00	10.3	7.312	1.252	7.476	41	7.476	7	0.000	0.000	7.380	0.0	5.0	0
15-Nov-89 05:00	16.9	3.268	1.248	3.328	39	3.328	8	0.000	0.000	7.848	0.0	5.1	0
15-Nov-89 06:00	19.4	3.578	1.243	3.630	33	3.630	7	20.400	12.000	0.000	8.3	-3.4	1
15-Nov-89 07:00	20.6	3.701	1.240	3.748	47	3.748	7	20.148	12.000	0.000	8.2	-3.3	1
15-Nov-89 08:00	17.5	3.346	1.238	3.381	60	3.381	7	11.394	3.668	0.000	5.9	-0.9	1
15-Nov-89 09:00	12.8	10.000	1.236	10.090	66	1.732	7	9.635	1.732	0.000	5.5	-0.5	1
15-Nov-89 10:00	11.4	9.090	1.236	9.169	69	1.135	7	8.575	1.135	0.000	5.3	-0.3	1
15-Nov-89 11:00	10.8	8.277	1.235	8.343	71	0.861	8	0.000	0.000	8.226	0.0	5.2	0
15-Nov-89 12:00	10.8	8.277	1.234	8.340	63	2.565	7	0.000	0.000	7.110	0.0	5.0	0
15-Nov-89 13:00	10.8	8.277	1.234	8.337	57	4.961	7	0.000	0.000	6.606	0.0	4.9	0
15-Nov-89 14:00	10.3	7.312	1.235	7.370	54	6.691	7	0.000	0.000	7.020	0.0	4.9	0
15-Nov-89 15:00	9.2	5.825	1.237	5.881	52	5.881	7	0.000	0.000	6.912	0.0	4.9	0
15-Nov-89 16:00	8.6	5.222	1.237	5.273	49	5.273	8	0.000	0.000	8.136	0.0	5.2	0
15-Nov-89 17:00	7.8	4.153	1.241	4.207	45	4.207	7	0.000	0.000	7.470	0.0	5.0	0
15-Nov-89 18:00	6.7	2.922	1.242	2.961	40	2.961	7	0.000	0.000	7.416	0.0	5.0	0
15-Nov-89 19:00	6.7	2.922	1.242	2.963	35	2.963	8	21.822	12.000	0.000	8.8	-3.6	1
15-Nov-89 20:00	7.2	3.574	1.243	3.626	47	3.626	8	21.963	12.000	0.000	8.8	-3.6	1
15-Nov-89 21:00	7.2	3.574	1.245	3.632	61	3.373	8	11.687	3.373	0.000	5.9	-0.9	1
15-Nov-89 22:00	6.1	2.433	1.246	2.475	66	1.567	7	9.405	1.567	0.000	5.4	-0.5	1
15-Nov-89 23:00	6.7	2.922	1.248	2.976	69	1.135	9	10.231	1.135	0.000	5.6	-0.4	1
16-Nov-89 00:00	5.6	1.919	1.250	1.957	71	0.718	10	0.000	0.000	9.597	0.0	5.5	0
16-Nov-89 01:00	6.7	2.922	1.251	2.983	61	2.983	9	0.000	0.000	9.093	0.0	5.4	0
16-Nov-89 02:00	5.6	1.919	1.251	1.959	54	1.959	9	0.000	0.000	9.219	0.0	5.4	0
16-Nov-89 03:00	6.1	2.433	1.250	2.482	45	2.482	9	0.000	0.000	8.883	0.0	5.3	0
16-Nov-89 04:00	6.7	2.922	1.250	2.980	38	2.980	9	22.080	12.000	0.000	8.9	-3.6	1
16-Nov-89 05:00	7.8	4.153	1.249	4.234	50	4.234	9	20.519	10.286	0.000	8.3	-3.0	1
16-Nov-89 06:00	7.8	4.153	1.249	4.234	63	2.565	8	11.384	2.565	0.000	5.9	-0.7	1
16-Nov-89 07:00	7.2	3.574	1.248	3.641	67	1.415	8	9.842	1.415	0.000	5.5	-0.4	1
16-Nov-89 08:00	7.8	4.153	1.246	4.225	69	0.999	8	0.000	0.000	8.190	0.0	5.2	0
16-Nov-89 09:00	9.2	5.825	1.245	5.922	61	3.089	8	0.000	0.000	8.421	0.0	5.2	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
16-Nov-89 10:00	9.7	6.594	1.244	6.699	55	5.722	8	0.000	0.000	8.001	0.0	5.1	0
16-Nov-89 11:00	9.7	6.594	1.244	6.694	51	6.694	10	0.000	0.000	9.597	0.0	5.5	0
16-Nov-89 12:00	10.8	8.277	1.244	8.409	46	8.409	8	0.000	0.000	8.295	0.0	5.2	0
16-Nov-89 13:00	9.2	5.825	1.246	5.923	44	5.923	8	0.000	0.000	7.707	0.0	5.1	0
16-Nov-89 14:00	5.6	1.919	1.249	1.956	41	1.956	8	0.000	0.000	8.190	0.0	5.2	0
16-Nov-89 15:00	3.1	0.000	1.243	0.000	33	0.000	8	21.534	12.000	0.000	8.7	-3.5	1
16-Nov-89 16:00	3.1	0.000	1.248	0.000	44	0.000	9	22.962	12.000	0.000	9.2	-3.7	1
16-Nov-89 17:00	3.6	0.667	1.251	0.681	54	0.681	9	16.052	6.691	0.000	7.0	-1.7	1
16-Nov-89 18:00	3.6	0.667	1.253	0.682	60	0.682	9	12.743	3.373	0.000	6.2	-0.9	1
16-Nov-89 19:00	3.1	0.000	1.254	0.000	64	0.000	10	12.794	2.329	0.000	6.2	-0.7	1
16-Nov-89 20:00	1.9	0.000	1.254	0.000	66	0.000	10	12.329	1.732	0.000	6.1	-0.5	1
16-Nov-89 21:00	3.6	0.667	1.252	0.681	67	0.681	9	10.913	1.415	0.000	5.8	-0.4	1
16-Nov-89 22:00	3.1	0.000	1.252	0.000	69	0.000	8	10.075	1.135	0.000	5.6	-0.4	1
16-Nov-89 23:00	3.1	0.000	1.250	0.000	70	0.000	10	0.000	0.000	9.933	0.0	5.5	0
17-Nov-89 00:00	3.1	0.000	1.249	0.000	59	0.000	8	0.000	0.000	8.226	0.0	5.2	0
17-Nov-89 01:00	5.6	1.919	1.247	1.952	50	1.952	8	0.000	0.000	7.794	0.0	5.1	0
17-Nov-89 02:00	5.3	1.691	1.246	1.720	43	1.720	8	0.000	0.000	7.902	0.0	5.1	0
17-Nov-89 03:00	5.6	1.919	1.246	1.951	36	1.951	8	21.084	12.000	0.000	8.5	-3.5	1
17-Nov-89 04:00	7.2	3.574	1.246	3.634	48	3.634	7	20.850	12.000	0.000	8.4	-3.4	1
17-Nov-89 05:00	7.2	3.574	1.245	3.631	61	3.089	8	11.670	3.089	0.000	5.9	-0.8	1
17-Nov-89 06:00	9.7	6.594	1.242	6.688	66	1.732	7	9.347	1.732	0.000	5.4	-0.5	1
17-Nov-89 07:00	11.4	9.090	1.241	9.211	69	1.135	7	8.395	1.135	0.000	[illegible].2	-0.3	1
17-Nov-89 08:00	13.3	10.000	1.238	10.108	71	0.718	7	0.000	0.000	7.020	0.0	4.9	0
17-Nov-89 09:00	13.9	10.000	1.233	10.069	64	2.112	7	0.000	0.000	7.218	0.0	5.0	0
17-Nov-89 10:00	12.8	10.000	1.231	10.052	58	4.291	7	0.000	0.000	6.858	0.0	4.9	0
17-Nov-89 11:00	15.0	9.700	1.231	9.750	54	6.170	8	0.000	0.000	8.226	0.0	5.2	0
17-Nov-89 12:00	12.8	10.000	1.231	10.049	50	10.049	7	0.000	0.000	7.110	0.0	5.0	0
17-Nov-89 13:00	11.9	9.829	1.231	9.880	51	9.058	7	0.000	0.000	6.606	0.0	4.9	0
17-Nov-89 14:00	9.7	6.594	1.232	6.632	51	6.632	7	0.000	0.000	7.020	0.0	4.9	0
17-Nov-89 15:00	7.8	4.153	1.234	4.184	49	4.184	7	0.000	0.000	6.912	0.0	4.9	0
17-Nov-89 16:00	6.1	2.433	1.233	2.449	45	2.449	8	0.000	0.000	8.136	0.0	5.2	0
17-Nov-89 17:00	6.1	2.433	1.234	2.449	38	2.449	7	20.940	12.000	0.000	8.5	-3.4	1
17-Nov-89 18:00	8.3	4.865	1.233	4.896	51	4.896	7	18.779	10.286	0.000	7.8	-2.8	1
17-Nov-89 19:00	8.6	5.222	1.232	5.253	64	2.329	8	11.402	2.329	0.000	5.9	-0.7	1
17-Nov-89 20:00	9.7	6.594	1.230	6.621	68	1.415	8	10.547	1.415	0.000	5.7	-0.4	1
17-Nov-89 21:00	10.8	8.277	1.229	8.306	70	0.999	8	0.000	0.000	7.596	0.0	5.1	0
17-Nov-89 22:00	10.8	8.277	1.229	8.303	63	2.565	7	0.000	0.000	7.164	0.0	5.0	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
17-Nov-89 23:00	15.6	8.200	1.227	8.215	57	4.961	9	0.000	0.000	8.514	0.0	5.2	0
18-Nov-89 00:00	15.0	9.700	1.227	9.714	52	8.090	8	0.000	0.000	8.226	0.0	5.2	0
18-Nov-89 01:00	13.3	10.000	1.226	10.007	50	10.007	8	0.000	0.000	7.794	0.0	5.1	0
18-Nov-89 02:00	12.8	10.000	1.225	10.000	50	10.000	8	0.000	0.000	7.902	0.0	5.1	0
18-Nov-89 03:00	13.3	10.000	1.225	10.001	49	10.001	8	0.000	0.000	7.614	0.0	5.1	0
18-Nov-89 04:00	13.3	10.000	1.225	9.998	50	9.998	7	0.000	0.000	7.380	0.0	5.0	0
18-Nov-89 05:00	14.4	9.959	1.224	9.953	50	9.953	8	0.000	0.000	7.848	0.0	5.1	0
18-Nov-89 06:00	13.3	10.000	1.223	9.984	50	9.984	7	0.000	0.000	6.930	0.0	4.9	0
18-Nov-89 07:00	14.4	9.959	1.223	9.947	51	9.947	7	0.000	0.000	6.678	0.0	4.9	0
18-Nov-89 08:00	14.4	9.959	1.223	9.940	52	8.090	7	0.000	0.000	7.020	0.0	4.9	0
18-Nov-89 09:00	13.9	10.000	1.223	9.980	51	9.058	7	0.000	0.000	7.218	0.0	5.0	0
18-Nov-89 10:00	15.6	8.200	1.223	8.184	51	8.184	7	0.000	0.000	6.858	0.0	4.9	0
18-Nov-89 11:00	11.4	9.090	1.223	9.079	50	9.079	8	0.000	0.000	8.226	0.0	5.2	0
18-Nov-89 12:00	8.3	4.865	1.227	4.873	49	4.873	7	0.000	0.000	7.110	0.0	5.0	0
18-Nov-89 13:00	8.3	4.865	1.234	4.900	45	4.900	7	0.000	0.000	6.606	0.0	4.9	0
18-Nov-89 14:00	9.2	5.825	1.236	5.877	42	5.877	7	0.000	0.000	7.020	0.0	4.9	0
18-Nov-89 15:00	8.3	4.865	1.240	4.926	40	4.926	7	0.000	0.000	6.912	0.0	4.9	0
18-Nov-89 16:00	7.2	3.574	1.241	3.621	36	3.621	8	21.606	12.000	0.000	8.7	-3.5	1
18-Nov-89 17:00	6.1	2.433	1.244	2.471	49	2.471	7	19.852	11.120	0.000	8.1	-3.1	1
18-Nov-89 18:00	7.8	4.153	1.247	4.229	61	3.089	7	11.238	3.089	0.000	5.8	-0.8	1
18-Nov-89 19:00	8.6	5.222	1.248	5.321	66	1.567	8	10.593	1.567	0.000	5.7	-0.5	1
18-Nov-89 20:00	8.6	5.222	1.248	5.322	69	1.135	8	10.213	1.135	0.000	5.6	-0.4	1
18-Nov-89 21:00	5.3	1.691	1.251	1.727	71	0.718	8	0.000	0.000	7.596	0.0	5.1	0
18-Nov-89 22:00	5.3	1.691	1.254	1.731	63	1.731	7	0.000	0.000	7.164	0.0	5.0	0
18-Nov-89 23:00	5.3	1.691	1.254	1.731	57	1.731	9	0.000	0.000	8.514	0.0	5.2	0
19-Nov-89 00:00	4.2	1.008	1.255	1.032	49	1.032	11	24.438	12.000	0.000	9.7	-3.9	1
19-Nov-89 01:00	4.7	1.355	1.257	1.390	60	1.390	10	14.766	3.668	0.000	6.7	-1.0	1
19-Nov-89 02:00	6.1	2.433	1.256	2.494	64	2.112	11	13.356	2.112	0.000	6.3	-0.7	1
19-Nov-89 03:00	5.3	1.691	1.259	1.738	68	1.272	10	12.049	1.272	0.000	6.0	-0.4	1
19-Nov-89 04:00	5.6	1.919	1.258	1.971	70	0.999	10	0.000	0.000	9.840	0.0	5.5	0
19-Nov-89 05:00	3.1	0.000	1.260	0.000	60	0.000	10	14.555	3.373	0.000	6.6	-1.0	1
19-Nov-89 06:00	5.6	1.919	1.259	1.973	63	1.973	9	12.539	2.565	0.000	6.1	-0.7	1
19-Nov-89 07:00	4.2	1.008	1.260	1.037	67	1.037	9	11.145	1.567	0.000	5.8	-0.5	1
19-Nov-89 08:00	4.2	1.008	1.261	1.037	69	1.037	9	11.077	1.135	0.000	5.8	-0.4	1
19-Nov-89 09:00	4.7	1.355	1.260	1.394	71	0.718	10	0.000	0.000	9.624	0.0	5.5	0
19-Nov-89 10:00	9.2	5.825	1.258	5.981	61	3.089	9	0.000	0.000	9.144	0.0	5.4	0
19-Nov-89 11:00	3.1	0.000	1.257	0.000	54	0.000	11	18.305	6.691	0.000	7.7	-1.9	1

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
19-Nov-89 12:00	3.1	0.000	1.259	0.000	59	0.000	9	14.147	3.975	0.000	6.5	-1.1	1
19-Nov-89 13:00	7.2	3.574	1.252	3.652	63	2.565	9	12.107	2.565	0.000	6.0	-0.7	1
19-Nov-89 14:00	3.6	0.667	1.248	0.680	67	0.680	9	11.601	1.567	0.000	5.9	-0.5	1
19-Nov-89 15:00	2.5	0.000	1.251	0.000	69	0.000	9	10.933	1.135	0.000	5.8	-0.4	1
19-Nov-89 16:00	2.5	0.000	1.255	0.000	70	0.000	11	12.409	0.999	0.000	6.1	-0.4	1
19-Nov-89 17:00	1.7	0.000	1.267	0.000	71	0.000	10	0.000	0.000	9.960	0.0	5.5	0
19-Nov-89 18:00	1.1	0.000	1.266	0.000	60	0.000	10	0.000	0.000	9.888	0.0	5.5	0
19-Nov-89 19:00	1.1	0.000	1.268	0.000	49	0.000	11	24.606	12.000	0.000	9.8	-4.0	1
19-Nov-89 20:00	1.7	0.000	1.267	0.000	59	0.000	11	15.995	3.975	0.000	7.0	-1.2	1
19-Nov-89 21:00	1.7	0.000	1.267	0.000	63	0.000	10	13.427	2.565	0.000	6.3	-0.8	1
19-Nov-89 22:00	1.9	0.000	1.266	0.000	65	0.000	10	12.161	1.913	0.000	6.0	-0.6	1
19-Nov-89 23:00	2.5	0.000	1.265	0.000	66	0.000	11	13.593	1.567	0.000	6.4	-0.5	1
20-Nov-89 00:00	1.9	0.000	1.264	0.000	68	0.000	10	11.648	1.415	0.000	5.9	-0.5	1
20-Nov-89 01:00	1.9	0.000	1.263	0.000	69	0.000	9	10.810	1.135	0.000	5.7	-0.4	1
20-Nov-89 02:00	1.9	0.000	1.262	0.000	70	0.000	9	0.000	0.000	9.219	0.0	5.4	0
20-Nov-89 03:00	1.7	0.000	1.263	0.000	60	0.000	9	0.000	0.000	8.883	0.0	5.3	0
20-Nov-89 04:00	1.9	0.000	1.262	0.000	50	0.000	9	0.000	0.000	8.610	0.0	5.3	0
20-Nov-89 05:00	2.5	0.000	1.261	0.000	41	0.000	9	0.000	0.000	9.156	0.0	5.4	0
20-Nov-89 06:00	3.6	0.667	1.262	0.687	31	0.687	8	21.555	12.000	0.000	8.7	-3.5	1
20-Nov-89 07:00	3.1	0.000	1.262	0.000	41	0.000	8	21.261	12.000	0.000	8.6	-3.5	1
20-Nov-89 08:00	3.6	0.667	1.262	0.687	52	0.687	8	18.111	9.058	0.000	7.6	-2.4	1
20-Nov-89 09:00	3.6	0.667	1.260	0.686	60	0.686	8	12.795	3.668	0.000	6.2	-1.0	1
20-Nov-89 10:00	2.5	0.000	1.261	0.000	64	0.000	8	11.051	2.329	0.000	5.8	-0.6	1
20-Nov-89 11:00	3.6	0.667	1.249	0.680	65	0.680	10	12.014	1.732	0.000	6.0	-0.5	1
20-Nov-89 12:00	4.2	1.008	1.244	1.023	68	1.023	8	10.346	1.415	0.000	5.6	-0.4	1
20-Nov-89 13:00	4.2	1.008	1.243	1.022	70	0.999	8	0.000	0.000	7.707	0.0	5.1	0
20-Nov-89 14:00	5.3	1.691	1.247	1.722	62	1.722	8	0.000	0.000	8.190	0.0	5.2	0
20-Nov-89 15:00	6.1	2.433	1.251	2.483	55	2.483	8	0.000	0.000	8.064	0.0	5.2	0
20-Nov-89 16:00	5.6	1.919	1.252	1.961	48	1.961	9	0.000	0.000	9.492	0.0	5.4	0
20-Nov-89 17:00	5.3	1.691	1.258	1.737	39	1.737	9	0.000	0.000	8.715	0.0	5.3	0
20-Nov-89 18:00	5.3	1.691	1.259	1.738	31	1.738	9	22.122	12.000	0.000	8.9	-3.6	1
20-Nov-89 19:00	5.6	1.919	1.258	1.970	43	1.970	10	23.214	12.000	0.000	9.3	-3.8	1
20-Nov-89 20:00	8.3	4.865	1.261	5.007	55	5.007	10	16.715	6.170	0.000	7.2	-1.7	1
20-Nov-89 21:00	5.6	1.919	1.266	1.982	64	1.982	9	11.682	2.112	0.000	5.9	-0.6	1
20-Nov-89 22:00	6.7	2.922	1.265	3.017	68	1.415	8	10.409	1.415	0.000	5.6	-0.4	1
20-Nov-89 23:00	3.6	0.667	1.268	0.690	70	0.690	10	0.000	0.000	9.933	0.0	5.5	0
21-Nov-89 00:00	2.5	0.000	1.271	0.000	60	0.000	10	0.000	0.000	9.597	0.0	5.5	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
21-Nov-89 01:00	1.7	0.000	1.273	0.000	49	0.000	9	0.000	0.000	9.093	0.0	5.4	0
21-Nov-89 02:00	3.1	0.000	1.274	0.000	39	0.000	9	0.000	0.000	9.219	0.0	5.4	0
21-Nov-89 03:00	1.9	0.000	1.276	0.000	29	0.000	9	22.353	12.000	0.000	9.0	-3.6	1
21-Nov-89 04:00	3.1	0.000	1.273	0.000	39	0.000	9	22.080	12.000	0.000	8.9	-3.6	1
21-Nov-89 05:00	1.7	0.000	1.276	0.000	49	0.000	9	21.538	11.120	0.000	8.7	-3.3	1
21-Nov-89 06:00	1.1	0.000	1.274	0.000	59	0.000	8	12.752	3.975	0.000	6.2	-1.0	1
21-Nov-89 07:00	1.1	0.000	1.276	0.000	62	0.000	8	11.330	2.819	0.000	5.8	-0.7	1
21-Nov-89 08:00	1.7	0.000	1.277	0.000	65	0.000	8	10.799	1.913	0.000	5.7	-0.5	1
21-Nov-89 09:00	1.9	0.000	1.276	0.000	66	0.000	8	10.662	1.567	0.000	5.7	-0.5	1
21-Nov-89 10:00	1.1	0.000	1.269	0.000	68	0.000	8	10.052	1.415	0.000	5.6	-0.4	1
21-Nov-89 11:00	2.5	0.000	1.265	0.000	69	0.000	10	11.314	1.135	0.000	5.8	-0.4	1
21-Nov-89 12:00	2.5	0.000	1.260	0.000	70	0.000	8	0.000	0.000	8.295	0.0	5.2	0
21-Nov-89 13:00	3.1	0.000	1.255	0.000	61	0.000	8	0.000	0.000	7.707	0.0	5.1	0
21-Nov-89 14:00	3.1	0.000	1.265	0.000	52	0.000	8	0.000	0.000	8.190	0.0	5.2	0
21-Nov-89 15:00	3.1	0.000	1.267	0.000	43	0.000	8	0.000	0.000	8.064	0.0	5.2	0
21-Nov-89 16:00	6.7	2.922	1.266	3.020	35	3.020	9	22.962	12.000	0.000	9.2	-3.7	1
21-Nov-89 17:00	6.7	2.922	1.266	3.020	47	3.020	9	22.185	12.000	0.000	8.9	-3.6	1
21-Nov-89 18:00	5.3	1.691	1.267	1.749	60	1.749	9	12.743	3.373	0.000	6.2	-0.9	1
21-Nov-89 19:00	6.7	2.922	1.266	3.019	64	2.112	10	12.564	2.112	0.000	6.1	-0.6	1
21-Nov-89 20:00	6.7	2.922	1.266	3.019	68	1.272	10	11.809	1.272	0.000	6.0	-0.4	1
21-Nov-89 21:00	8.6	5.222	1.266	5.397	70	0.861	9	0.000	0.000	8.862	0.0	5.3	0
21-Nov-89 22:00	7.8	4.153	1.266	4.292	61	3.089	8	0.000	0.000	8.358	0.0	5.2	0
21-Nov-89 23:00	8.6	5.222	1.264	5.388	55	5.388	10	0.000	0.000	9.933	0.0	5.5	0
22-Nov-89 00:00	8.6	5.222	1.262	5.378	48	5.378	5	0.000	0.000	5.484	0.0	4.7	0
22-Nov-89 01:00	9.2	5.825	1.260	5.991	47	5.991	5	0.000	0.000	5.196	0.0	4.6	0
22-Nov-89 02:00	10.3	7.312	1.257	7.505	46	7.505	5	0.000	0.000	5.268	0.0	4.6	0
22-Nov-89 03:00	10.8	8.277	1.255	8.478	47	8.478	5	0.000	0.000	5.076	0.0	4.6	0
22-Nov-89 04:00	11.4	9.090	1.253	9.294	48	9.294	5	0.000	0.000	4.920	0.0	4.6	0
22-Nov-89 05:00	13.3	10.000	1.249	10.200	51	10.200	5	0.000	0.000	5.232	0.0	4.6	0
22-Nov-89 06:00	11.4	9.090	1.247	9.253	54	6.691	5	0.000	0.000	4.620	0.0	4.5	0
22-Nov-89 07:00	12.8	10.000	1.247	10.179	54	6.170	4	0.000	0.000	4.452	0.0	4.5	0
22-Nov-89 08:00	13.9	10.000	1.244	10.159	54	6.170	5	0.000	0.000	4.680	0.0	4.5	0
22-Nov-89 09:00	16.4	3.290	1.245	3.343	54	3.343	5	0.000	0.000	4.812	0.0	4.5	0
22-Nov-89 10:00	17.5	3.346	1.244	3.398	52	3.398	5	0.000	0.000	4.572	0.0	4.5	0
22-Nov-89 11:00	16.9	3.268	1.239	3.306	50	3.306	5	0.000	0.00C	5.484	0.0	4.7	0
22-Nov-89 12:00	20.6	3.701	1.237	3.739	46	3.739	5	0.000	0.000	4.740	0.0	4.5	0
22-Nov-89 13:00	19.4	3.578	1.237	3.611	44	3.611	4	0.000	0.000	4.404	0.0	4.5	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
22-Nov-89 14:00	20.6	3.701	1.234	3.727	42	3.727	5	0.000	0.000	4.680	0.0	4.5	0
22-Nov-89 15:00	20.6	3.701	1.229	3.714	40	3.714	5	0.000	0.000	4.608	0.0	4.5	0
22-Nov-89 16:00	23.6	4.018	1.226	4.023	38	4.023	5	18.894	12.000	0.000	7.8	-3.2	1
22-Nov-89 17:00	23.6	4.018	1.222	4.007	52	4.007	5	13.809	8.090	0.000	6.4	-1.9	1
22-Nov-89 18:00	21.7	3.819	1.221	3.807	62	2.819	5	8.483	2.819	0.000	5.2	-0.7	1
22-Nov-89 19:00	10.8	8.277	1.220	8.243	67	1.567	6	7.809	1.567	0.000	5.1	-0.4	1
22-Nov-89 20:00	10.3	7.312	1.220	7.280	70	0.999	6	0.000	0.000	5.664	0.0	4.7	0
22-Nov-89 21:00	9.2	5.825	1.220	5.801	64	2.112	5	0.000	0.000	5.064	0.0	4.6	0
22-Nov-89 22:00	8.6	5.222	1.220	5.199	60	3.373	5	0.000	0.000	4.776	0.0	4.5	0
22-Nov-89 23:00	11.4	9.090	1.223	9.073	58	4.291	6	0.000	0.000	5.676	0.0	4.7	0
23-Nov-89 00:00	10.3	7.312	1.224	7.304	55	5.722	14	20.059	5.722	0.000	8.2	-1.8	1
23-Nov-89 01:00	11.4	9.090	1.224	9.082	65	1.913	13	15.599	1.913	0.000	6.9	-0.7	1
23-Nov-89 02:00	12.8	10.000	1.225	10.002	68	1.272	13	15.067	1.272	0.000	6.8	-0.5	1
23-Nov-89 03:00	12.8	10.000	1.228	10.028	70	0.861	13	14.058	0.861	0.000	6.5	-0.3	1
23-Nov-89 04:00	10.8	8.277	1.228	8.294	72	0.568	12	13.254	0.568	0.000	6.3	-0.2	1
23-Nov-89 05:00	11.4	9.090	1.229	9.118	73	0.414	13	13.790	0.414	0.000	6.4	-0.2	1
23-Nov-89 06:00	13.9	10.000	1.228	10.024	74	0.260	12	12.016	0.260	0.000	6.0	-0.1	1
23-Nov-89 07:00	11.4	9.090	1.229	9.121	74	0.116	11	11.342	0.116	0.000	5.8	0.0	1
23-Nov-89 08:00	6.1	2.433	1.239	2.461	74	0.116	12	11.912	0.116	0.000	6.0	0.0	1
23-Nov-89 09:00	5.8	1.919	1.236	1.936	74	0.116	12	12.242	0.116	0.000	6.1	0.0	1
23-Nov-89 10:00	6.1	2.433	1.234	2.450	75	0.116	11	11.642	0.116	0.000	5.9	0.0	1
23-Nov-89 11:00	10.3	7.312	1.230	7.345	75	0.000	14	13.710	0.000	0.000	6.4	0.0	1
23-Nov-89 12:00	10.8	8.277	1.227	8.290	75	0.000	12	11.850	0.000	0.000	6.0	0.0	1
23-Nov-89 13:00	10.8	8.277	1.226	8.282	75	0.000	11	11.010	0.000	0.000	5.8	0.0	1
23-Nov-89 14:00	11.9	9.829	1.234	9.898	75	0.000	12	11.700	0.000	0.000	5.9	0.0	1
23-Nov-89 15:00	10.8	8.277	1.234	8.335	75	0.000	12	11.520	0.000	0.000	5.9	0.0	1
23-Nov-89 16:00	4.7	1.355	1.237	1.369	75	0.000	14	13.560	0.000	0.000	6.4	0.0	1
23-Nov-89 17:00	1.9	0.000	1.238	0.000	75	0.000	12	12.450	0.000	0.000	6.1	0.0	1
23-Nov-89 18:00	3.1	0.000	1.246	0.000	75	0.000	12	12.360	0.000	0.000	6.1	0.0	1
23-Nov-89 19:00	2.5	0.000	1.241	0.000	75	0.000	14	13.920	0.000	0.000	6.5	0.0	1
23-Nov-89 20:00	7.2	3.574	1.238	3.612	75	0.000	14	14.160	0.000	0.000	6.5	0.0	1
23-Nov-89 21:00	6.7	2.922	1.239	2.954	75	0.000	13	12.660	0.000	0.000	6.2	0.0	1
23-Nov-89 22:00	7.2	3.574	1.237	3.609	75	0.000	12	11.940	0.000	0.000	6.0	0.0	1
23-Nov-89 23:00	7.8	4.153	1.237	4.193	75	0.000	14	14.190	0.000	0.000	6.5	0.0	1
24-Nov-89 00:00	8.3	4.865	1.237	4.912	75	0.000	11	10.968	0.000	0.000	5.8	0.0	1
24-Nov-89 01:00	7.8	4.153	1.236	4.192	75	0.000	10	10.392	0.000	0.000	5.6	0.0	1
24-Nov-89 02:00	9.7	6.594	1.237	6.659	75	0.000	11	10.536	0.000	0.000	5.7	0.0	1

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
24-Nov-89 03:00	5.3	1.691	1.239	1.711	75	0.000	10	10.152	0.000	0.000	5.6	0.0	1
24-Nov-89 04:00	6.1	2.433	1.237	2.457	75	0.000	10	0.000	0.000	9.840	0.0	5.5	0
24-Nov-89 05:00	7.2	3.574	1.236	3.606	64	2.112	10	13.284	2.112	0.000	6.3	-0.7	1
24-Nov-89 06:00	6.1	2.433	1.236	2.454	68	1.415	9	11.291	1.415	0.000	5.8	-0.4	1
24-Nov-89 07:00	7.8	4.153	1.236	4.190	70	0.999	9	0.000	0.000	8.904	0.0	5.3	0
24-Nov-89 08:00	4.2	1.008	1.242	1.021	61	1.021	9	0.000	0.000	9.360	0.0	5.4	0
24-Nov-89 09:00	5.3	1.691	1.239	1.710	52	1.710	10	0.000	0.000	9.624	0.0	5.5	0
24-Nov-89 10:00	6.1	2.433	1.236	2.454	43	2.454	9	0.000	0.000	9.144	0.0	5.4	0
24-Nov-89 11:00	6.1	2.433	1.225	2.433	35	2.433	11	24.438	12.000	0.000	9.7	-3.9	1
24-Nov-89 12:00	9.2	5.825	1.233	5.864	47	5.864	9	22.950	12.000	0.000	9.2	-3.7	1
24-Nov-89 13:00	7.2	3.574	1.224	3.571	62	2.819	9	12.347	2.819	0.000	6.1	-0.8	1
24-Nov-89 14:00	7.8	4.153	1.234	4.184	67	1.567	9	11.601	1.567	0.000	5.9	-0.5	1
24-Nov-89 15:00	7.8	4.153	1.228	4.165	70	0.999	9	0.000	0.000	9.216	0.0	5.4	0
24-Nov-89 16:00	6.1	2.433	1.233	2.449	60	2.449	11	14.939	3.373	0.000	6.7	-1.0	1
24-Nov-89 17:00	9.7	6.594	1.237	6.659	65	1.913	10	12.569	1.913	0.000	6.1	-0.8	1
24-Nov-89 18:00	6.7	2.922	1.238	2.953	69	1.135	10	11.605	1.135	0.000	5.9	-0.4	1
24-Nov-89 19:00	4.2	1.008	1.239	1.019	70	0.861	11	12.504	0.861	0.000	6.1	-0.3	1
24-Nov-89 20:00	5.3	1.691	1.237	1.708	72	0.568	11	12.282	0.568	0.000	6.1	-0.2	1
24-Nov-89 21:00	7.2	3.574	1.235	3.603	73	0.414	10	10.838	0.414	0.000	5.7	-0.2	1
24-Nov-89 22:00	5.6	1.919	1.236	1.936	74	0.260	10	0.000	0.000	9.552	0.0	5.5	0
24-Nov-89 23:00	7.2	3.574	1.237	3.609	63	2.329	11	14.402	2.329	0.000	6.6	-0.7	1
25-Nov-89 00:00	5.3	1.691	1.239	1.710	67	1.415	10	11.648	1.415	0.000	5.9	-0.5	1
25-Nov-89 01:00	6.1	2.433	1.239	2.461	70	0.999	9	0.000	0.000	9.093	0.0	5.4	0
25-Nov-89 02:00	3.6	0.667	1.241	0.676	61	0.676	9	0.000	0.000	9.219	0.0	5.4	0
25-Nov-89 03:00	4.2	1.008	1.241	1.021	51	1.021	9	0.000	0.000	8.883	0.0	5.3	0
25-Nov-89 04:00	5.6	1.919	1.240	1.942	42	1.942	9	0.000	0.000	8.610	0.0	5.3	0
25-Nov-89 05:00	5.3	1.691	1.236	1.706	34	1.706	9	22.626	12.000	0.000	9.0	-3.7	1
25-Nov-89 06:00	4.7	1.355	1.240	1.372	46	1.372	8	21.555	12.000	0.000	8.7	-3.5	1
25-Nov-89 07:00	6.1	2.433	1.241	2.463	57	2.463	8	13.062	4.618	0.000	6.3	-1.2	1
25-Nov-89 08:00	4.2	1.008	1.242	1.022	64	1.022	8	11.240	2.329	0.000	5.8	-0.6	1
25-Nov-89 09:00	1.1	0.000	1.244	0.000	66	0.000	8	10.662	1.567	0.000	5.7	-0.5	1
25-Nov-89 10:00	1.1	0.000	1.243	0.000	68	0.000	8	10.052	1.415	0.000	5.6	-0.4	1
25-Nov-89 11:00	1.7	0.000	1.244	0.000	69	0.000	10	11.314	1.135	0.000	5.8	-0.4	1
25-Nov-89 12:00	1.7	0.000	1.242	0.000	70	0.000	8	0.000	0.000	8.295	0.0	5.2	0
25-Nov-89 13:00	1.7	0.000	1.242	0.000	61	0.000	8	0.000	0.000	7.707	0.0	5.1	0
25-Nov-89 14:00	3.6	0.667	1.240	0.675	52	0.675	8	0.000	0.000	8.190	0.0	5.2	0
25-Nov-89 15:00	0.0	0.000	1.245	0.000	44	0.000	8	0.000	0.000	8.064	0.0	5.2	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
25-Nov-89 16:00	3.1	0.000	1.246	0.000	35	0.000	9	22.962	12.000	0.000	9.2	-3.7	1
25-Nov-89 17:00	0.0	0.000	1.247	0.000	45	0.000	9	22.185	12.000	0.000	8.9	-3.6	1
25-Nov-89 18:00	1.9	0.000	1.250	0.000	56	0.000	9	14.609	5.325	0.000	6.6	-1.4	1
25-Nov-89 19:00	2.5	0.000	1.252	0.000	60	0.000	10	13.835	3.373	0.000	6.4	-0.9	1
25-Nov-89 20:00	1.9	0.000	1.252	0.000	63	0.000	10	13.211	2.565	0.000	6.3	-0.8	1
25-Nov-89 21:00	3.1	0.000	1.251	0.000	65	0.000	9	11.471	1.913	0.000	5.9	-0.6	1
25-Nov-89 22:00	4.2	1.008	1.251	1.029	67	1.029	8	10.599	1.567	0.000	5.7	-0.5	1
25-Nov-89 23:00	3.1	0.000	1.252	0.000	69	0.000	10	11.650	1.135	0.000	5.9	-0.4	1
26-Nov-89 00:00	3.6	0.667	1.252	0.682	70	0.682	11	12.529	0.999	0.000	6.1	-0.4	1
26-Nov-89 01:00	4.2	1.008	1.250	1.028	71	0.718	10	11.552	0.718	0.000	5.9	-0.3	1
26-Nov-89 02:00	3.6	0.667	1.252	0.681	73	0.414	11	11.246	0.414	0.000	5.8	-0.2	1
26-Nov-89 03:00	2.5	0.000	1.253	0.000	73	0.000	10	10.618	0.260	0.000	5.7	-0.1	1
26-Nov-89 04:00	3.6	0.667	1.253	0.682	73	0.260	10	0.000	0.000	9.840	0.0	5.5	0
26-Nov-89 05:00	2.5	0.000	1.252	0.000	63	0.000	10	13.763	2.565	0.000	6.4	-0.8	1
26-Nov-89 06:00	1.9	0.000	1.252	0.000	65	0.000	9	11.849	1.913	0.000	6.0	-0.6	1
26-Nov-89 07:00	2.5	0.000	1.251	0.000	67	0.000	9	11.145	1.567	0.000	5.8	-0.5	1
26-Nov-89 08:00	3.1	0.000	1.251	0.000	68	0.000	9	11.257	1.272	0.000	5.8	-0.4	1
26-Nov-89 09:00	3.1	0.000	1.248	0.000	69	0.000	10	11.341	1.135	0.000	5.8	-0.4	1
26-Nov-89 10:00	3.6	0.667	1.246	0.678	70	0.678	9	0.000	0.000	9.144	0.0	5.4	0
26-Nov-89 11:00	4.7	1.355	1.246	1.378	61	1.378	11	15.059	3.373	0.000	6.8	-1.0	1
26-Nov-89 12:00	6.1	2.433	1.243	2.469	65	1.913	9	12.089	1.913	0.000	6.0	-0.6	1
26-Nov-89 13:00	7.8	4.153	1.243	4.216	68	1.272	9	10.705	1.272	0.000	5.7	-0.4	1
26-Nov-89 14:00	9.2	5.825	1.244	5.916	70	0.861	9	0.000	0.000	9.360	0.0	5.4	0
26-Nov-89 15:00	10.3	7.312	1.247	7.443	61	3.373	9	0.000	0.000	9.216	0.0	5.4	0
26-Nov-89 16:00	11.9	9.829	1.246	9.998	53	6.691	11	18.185	6.691	0.000	7.6	-1.9	1
26-Nov-89 17:00	13.3	10.000	1.245	10.160	65	1.913	10	12.569	1.913	0.000	6.1	-0.6	1
26-Nov-89 18:00	7.2	3.574	1.242	3.624	68	1.272	10	11.785	1.272	0.000	5.9	-0.4	1
26-Nov-89 19:00	7.2	3.574	1.242	3.623	70	0.861	11	12.504	0.861	0.000	6.1	-0.3	1
26-Nov-89 20:00	6.1	2.433	1.241	2.465	72	0.568	11	12.282	0.568	0.000	6.1	-0.2	1
26-Nov-89 21:00	7.2	3.574	1.241	3.621	73	0.414	10	10.838	0.414	0.000	5.7	-0.2	1
26-Nov-89 22:00	9.2	5.825	1.240	5.898	73	0.260	10	0.000	0.000	9.552	0.0	5.5	0
26-Nov-89 23:00	9.7	6.594	1.240	6.677	63	2.565	11	14.651	2.565	0.000	6.6	-0.8	1
27-Nov-89 00:00	9.7	6.594	1.240	6.677	67	1.415	8	10.277	1.415	0.000	5.6	-0.4	1
27-Nov-89 01:00	9.7	6.594	1.240	6.672	70	0.999	8	0.000	0.000	7.794	0.0	5.1	0
27-Nov-89 02:00	10.8	8.277	1.239	8.373	62	2.819	8	0.000	0.000	7.902	0.0	5.1	0
27-Nov-89 03:00	13.3	10.000	1.239	10.112	56	5.325	8	0.000	0.000	7.614	0.0	5.1	0
27-Nov-89 04:00	13.9	10.000	1.237	10.102	52	8.090	7	0.000	0.000	7.380	0.0	5.0	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
27-Nov-89 05:00	15.8	6.096	1.235	6.145	51	6.145	8	0.000	0.000	7.848	0.0	5.1	0
27-Nov-89 06:00	16.4	3.290	1.234	3.313	47	3.313	7	0.000	0.000	6.930	0.0	4.9	0
27-Nov-89 07:00	16.9	3.268	1.233	3.290	43	3.290	7	0.000	0.000	6.678	0.0	4.9	0
27-Nov-89 08:00	17.5	3.346	1.232	3.365	38	3.365	7	20.490	12.000	0.000	8.3	-3.4	1
27-Nov-89 09:00	18.1	3.409	1.232	3.430	51	3.430	7	17.139	9.058	0.000	7.3	-2.3	1
27-Nov-89 10:00	18.1	3.409	1.231	3.427	62	2.819	7	10.397	2.819	0.000	5.6	-0.7	1
27-Nov-89 11:00	20.0	3.646	1.230	3.660	67	1.567	8	10.467	1.567	0.000	5.7	-0.5	1
27-Nov-89 12:00	20.0	3.646	1.230	3.661	69	1.135	7	8.827	1.135	0.000	5.3	-0.3	1
27-Nov-89 13:00	22.2	3.880	1.229	3.891	71	0.718	7	0.000	0.000	6.606	0.0	4.9	0
27-Nov-89 14:00	23.6	4.018	1.227	4.024	65	2.112	7	0.000	0.000	7.020	0.0	4.9	0
27-Nov-89 15:00	23.1	3.960	1.226	3.965	59	3.965	7	0.000	0.000	6.912	0.0	4.9	0
27-Nov-89 16:00	24.2	4.065	1.226	4.068	54	4.068	8	0.000	0.000	8.136	0.0	5.2	0
27-Nov-89 17:00	23.1	3.960	1.225	3.961	49	3.961	7	0.000	0.000	7.470	0.0	5.0	0
27-Nov-89 18:00	24.2	4.065	1.224	4.061	44	4.061	7	0.000	0.000	7.416	0.0	5.0	0
27-Nov-89 19:00	27.2	4.336	1.222	4.327	40	4.327	8	0.000	0.000	8.352	0.0	5.2	0
27-Nov-89 20:00	25.8	4.218	1.223	4.212	34	4.212	8	21.966	12.000	0.000	8.8	-3.6	1
27-Nov-89 21:00	27.8	4.377	1.222	4.366	48	4.366	8	21.066	12.000	0.000	8.5	-3.5	1
27-Nov-89 22:00	27.2	4.336	1.221	4.323	62	2.819	7	10.703	2.819	0.000	5.7	-0.7	1
27-Nov-89 23:00	26.1	4.244	1.220	4.228	67	1.567	9	10.755	1.567	0.000	5.7	-0.5	1
28-Nov-89 00:00	25.8	4.218	1.219	4.199	69	1.135	10	11.314	1.135	0.000	5.8	-0.4	1
28-Nov-89 01:00	15.0	9.700	1.232	9.759	71	0.718	9	0.000	0.000	9.093	0.0	5.4	0
28-Nov-89 02:00	14.4	9.959	1.239	10.075	62	2.819	9	0.000	0.000	9.219	0.0	5.4	0
28-Nov-89 03:00	15.0	9.700	1.242	9.832	54	6.170	9	0.000	0.000	8.883	0.0	5.3	0
28-Nov-89 04:00	13.3	10.000	1.242	10.139	50	10.139	9	0.000	0.000	8.610	0.0	5.3	0
28-Nov-89 05:00	8.6	5.222	1.246	5.310	49	5.310	9	0.000	0.000	9.156	0.0	5.4	0
28-Nov-89 06:00	9.2	5.825	1.247	5.930	43	5.930	8	0.000	0.000	8.085	0.0	5.2	0
28-Nov-89 07:00	9.2	5.825	1.249	5.937	39	5.937	8	0.000	0.000	7.791	0.0	5.1	0
28-Nov-89 08:00	5.6	1.919	1.251	1.959	36	1.959	8	21.660	12.000	0.000	8.7	-3.5	1
28-Nov-89 09:00	1.1	0.000	1.250	0.000	48	0.000	8	21.891	12.000	0.000	8.8	-3.6	1
28-Nov-89 10:00	2.5	0.000	1.251	0.000	58	0.000	8	12.973	4.291	0.000	6.2	-1.1	1
28-Nov-89 11:00	3.1	0.000	1.247	0.000	62	0.000	10	13.136	2.819	0.000	6.3	-0.8	1
28-Nov-89 12:00	5.6	1.919	1.243	1.947	64	1.947	8	11.115	2.112	0.000	5.8	-0.6	1
28-Nov-89 13:00	6.7	2.922	1.246	2.971	68	1.415	8	9.758	1.415	0.000	5.5	-0.4	1
28-Nov-89 14:00	7.8	4.153	1.245	4.222	70	0.999	8	0.000	0.000	8.190	0.0	5.2	0
28-Nov-89 15:00	9.2	5.825	1.245	5.919	62	2.819	8	0.000	0.000	8.064	0.0	5.2	0
28-Nov-89 16:00	11.4	9.090	1.244	9.233	55	5.722	9	0.000	0.000	9.492	0.0	5.4	0
28-Nov-89 17:00	9.2	5.825	1.244	5.916	50	5.916	9	0.000	0.000	8.715	0.0	5.3	0

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
28-Nov-89 18:00	9.7	6.594	1.243	6.691	45	6.691	9	0.000	0.000	8.652	0.0	5.3	0
28-Nov-89 19:00	10.8	8.277	1.243	8.402	42	8.402	10	0.000	0.000	9.744	0.0	5.5	0
28-Nov-89 20:00	12.2	9.988	1.243	10.138	38	10.138	10	23.382	12.000	0.000	9.3	-3.8	1
28-Nov-89 21:00	12.8	10.000	1.243	10.151	57	4.961	9	14.470	4.961	0.000	6.6	-1.3	1
28-Nov-89 22:00	13.9	10.000	1.243	10.151	65	1.913	8	10.967	1.913	0.000	5.3	-0.6	1
28-Nov-89 23:00	14.4	9.959	1.243	10.108	69	1.135	10	11.650	1.135	0.000	5.9	-0.4	1
29-Nov-89 00:00	13.3	10.000	1.242	10.142	71	0.861	10	0.000	0.000	9.597	0.0	5.5	0
29-Nov-89 01:00	13.3	10.000	1.243	10.149	61	3.373	9	0.000	0.000	9.093	0.0	5.4	0
29-Nov-89 02:00	12.2	9.988	1.244	10.145	54	6.691	9	0.000	0.000	9.219	0.0	5.4	0
29-Nov-89 03:00	11.9	9.829	1.245	9.986	49	9.986	9	0.000	0.000	8.883	0.0	5.3	0
29-Nov-89 04:00	13.9	10.000	1.243	10.149	48	10.149	9	0.000	0.000	8.610	0.0	5.3	0
29-Nov-89 05:00	13.3	10.000	1.244	10.153	47	10.153	9	0.000	0.000	9.156	0.0	5.4	0
29-Nov-89 06:00	12.8	10.000	1.243	10.149	46	10.149	8	0.000	0.000	8.065	0.0	5.2	0
29-Nov-89 07:00	14.4	9.959	1.243	10.105	46	10.105	8	0.000	0.000	7.791	0.0	5.1	0
29-Nov-89 08:00	13.9	10.000	1.244	10.154	46	10.154	8	0.000	0.000	8.190	0.0	5.2	0
29-Nov-89 09:00	15.0	9.700	1.245	9.859	45	9.859	8	0.000	0.000	8.421	0.0	5.2	0
29-Nov-89 10:00	15.6	8.200	1.244	8.325	44	8.325	8	0.000	0.000	8.001	0.0	5.1	0
29-Nov-89 11:00	15.0	9.700	1.244	9.848	43	9.848	10	0.000	0.000	9.597	0.0	5.5	0
29-Nov-89 12:00	13.9	10.000	1.243	10.146	41	10.146	8	0.000	0.000	8.295	0.0	5.2	0
29-Nov-89 13:00	15.6	8.200	1.243	8.319	40	8.319	8	0.000	0.000	7.707	0.0	5.1	0
29-Nov-89 14:00	15.0	9.700	1.242	9.831	39	9.831	8	0.000	0.000	8.190	0.0	5.2	0
29-Nov-89 15:00	13.3	10.000	1.242	10.139	38	10.139	8	21.534	12.000	0.000	8.7	-3.5	1
29-Nov-89 16:00	14.4	9.959	1.242	10.097	57	4.618	9	14.763	4.618	0.000	6.7	-1.2	1
29-Nov-89 17:00	14.4	9.959	1.243	10.104	65	1.913	9	11.324	1.913	0.000	5.8	-0.6	1
29-Nov-89 18:00	13.9	10.000	1.242	10.143	68	1.272	9	10.549	1.272	0.000	5.7	-0.4	1
29-Nov-89 19:00	14.4	9.959	1.242	10.101	70	0.861	10	0.000	0.000	9.744	0.0	5.5	0
29-Nov-89 20:00	14.4	9.959	1.244	10.112	60	3.373	10	0.000	0.000	9.912	0.0	5.5	0
29-Nov-89 21:00	13.9	10.000	1.244	10.156	52	7.318	9	0.000	0.000	8.862	0.0	5.3	0
29-Nov-89 22:00	13.9	10.000	1.244	10.156	49	10.156	8	0.000	0.000	8.358	0.0	5.2	0
29-Nov-89 23:00	13.9	10.000	1.244	10.156	48	10.156	10	0.000	0.000	9.933	0.0	5.5	0
30-Nov-89 00:00	12.2	9.988	1.244	10.143	46	10.143	11	24.438	12.000	0.000	9.7	-3.9	1
30-Nov-89 01:00	10.8	8.277	1.244	8.406	65	1.913	10	13.001	1.913	0.000	6.2	-0.6	1
30-Nov-89 02:00	8.6	5.222	1.245	5.307	68	1.272	11	12.433	1.272	0.000	6.1	-0.4	1
30-Nov-89 03:00	7.2	3.574	1.246	3.634	70	0.861	10	11.520	0.861	0.000	5.9	-0.3	1
30-Nov-89 04:00	6.1	2.433	1.246	2.475	72	0.568	10	0.000	0.000	9.840	0.0	5.5	0
30-Nov-89 05:00	4.2	1.008	1.247	1.026	62	1.026	10	14.286	3.089	0.000	6.6	-0.9	1
30-Nov-89 06:00	4.2	1.008	1.248	1.027	65	1.027	9	11.849	1.913	0.000	6.0	-0.6	1

Appendix B

Battery capacity= 77.000 kWh
Diesel capacity= 30.000 kW
Wind turbine capacity= 10.000 kW
Inverter capacity= 20.000 kW

Month: November, 1989

actual loads

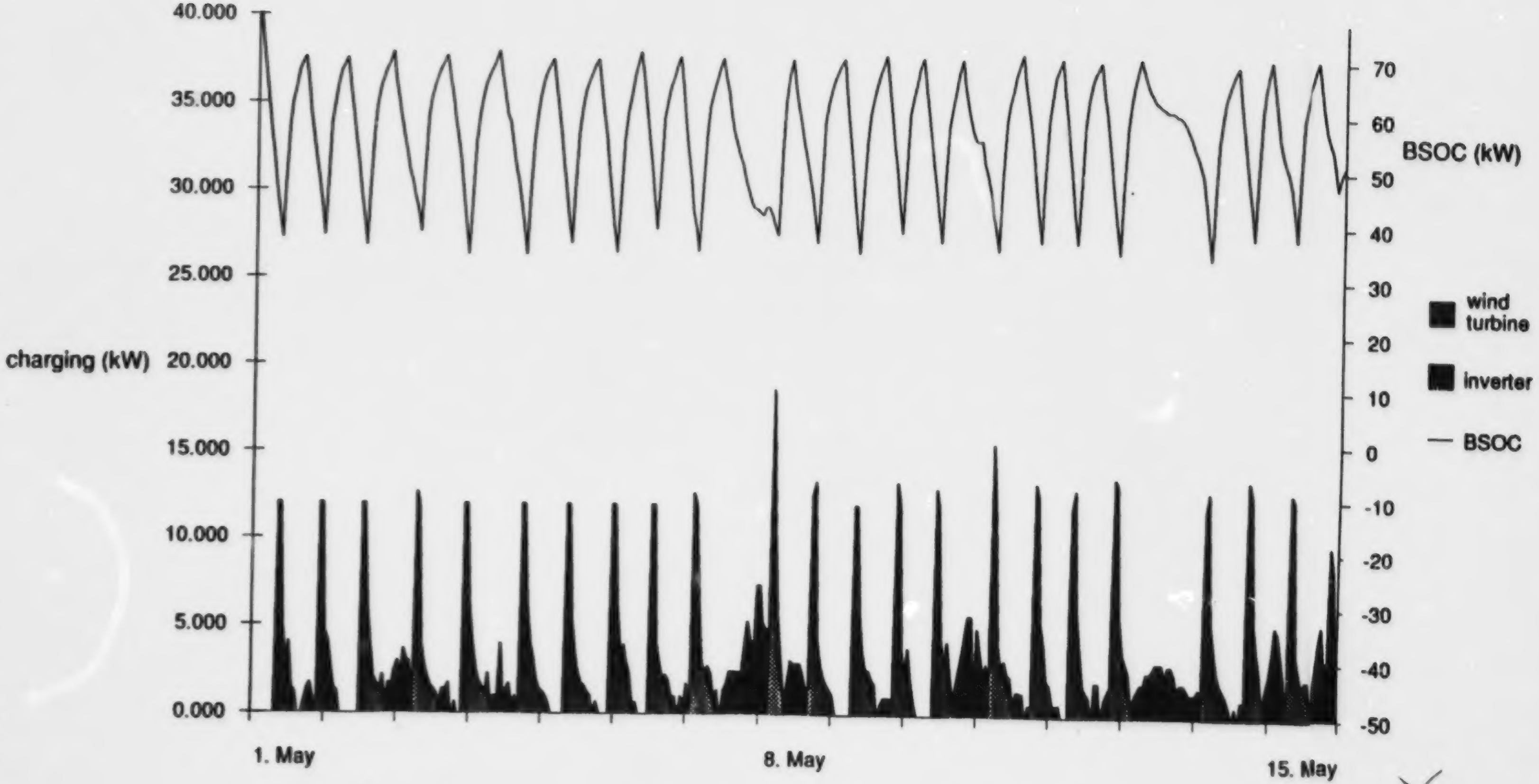
Date	Windspeed (m/s)	Potential turbine output @ std temp & press (kW)	Air density (kg/cu.m)	Potential turbine output at site (kW)	Battery state of charge (kWh)	Actual turbine output (kW)	Demand (kW)	Diesel load (kW)	Inverter charging load (kW)	Inverter demand load (kW)	Fuel used (l)	Fuel saved (l)	Diesel hours (hrs)
30-Nov-89 07:00	4.2	1.008	1.248	1.027	68	1.027	9	10.955	1.415	0.000	5.8	-0.4	1
30-Nov-89 08:00	6.1	2.433	1.257	2.496	70	0.999	9	0.000	0.000	9.360	0.0	5.4	0
30-Nov-89 09:00	5.3	1.691	1.256	1.734	60	1.734	10	0.000	0.000	9.624	0.0	5.5	0
30-Nov-89 10:00	2.5	0.000	1.256	0.000	51	0.000	9	0.000	0.000	9.144	0.0	5.4	0
30-Nov-89 11:00	4.2	1.008	1.252	1.029	41	1.029	11	24.438	12.000	0.000	9.7	-3.9	1
30-Nov-89 12:00	6.1	2.433	1.252	2.485	52	2.485	9	18.309	8.090	0.000	7.7	-2.2	1
30-Nov-89 13:00	7.8	4.153	1.249	4.236	61	3.089	9	12.630	3.089	0.000	6.1	-0.8	1
30-Nov-89 14:00	8.3	4.865	1.252	4.973	66	1.567	9	11.601	1.567	0.000	5.9	-0.5	1
30-Nov-89 15:00	8.3	4.865	1.253	4.975	69	1.135	9	10.933	1.135	0.000	5.8	-0.4	1
30-Nov-89 16:00	7.8	4.153	1.253	4.247	71	0.718	11	12.008	0.718	0.000	6.0	-0.3	1
30-Nov-89 17:00	7.2	3.574	1.253	3.656	72	0.568	10	0.000	0.000	9.960	0.0	5.5	0
30-Nov-89 18:00	9.2	5.825	1.252	5.952	62	2.819	10	0.000	0.000	9.888	0.0	5.5	0
30-Nov-89 19:00	10.8	8.277	1.250	8.447	53	6.691	11	18.473	6.691	0.000	7.7	-1.9	1
30-Nov-89 20:00	11.4	9.090	1.247	9.251	65	1.913	11	13.937	1.913	0.000	6.5	-0.6	1
30-Nov-89 21:00	11.9	9.829	1.246	9.995	68	1.272	10	12.025	1.272	0.000	6.0	-0.4	1
30-Nov-89 22:00	12.8	10.000	1.244	10.159	70	0.861	10	0.000	0.000	9.552	0.0	5.5	0
30-Nov-89 23:00	13.9	10.000	1.245	10.162	60	3.373	11	15.443	3.373	0.000	6.9	-1.0	1
TOTALS	9.736883			3647		2280	6257	5099	1438	2859	2387	1421	361

Appendix C

Monthly Analysis Graphs

based on 60% of actual loads

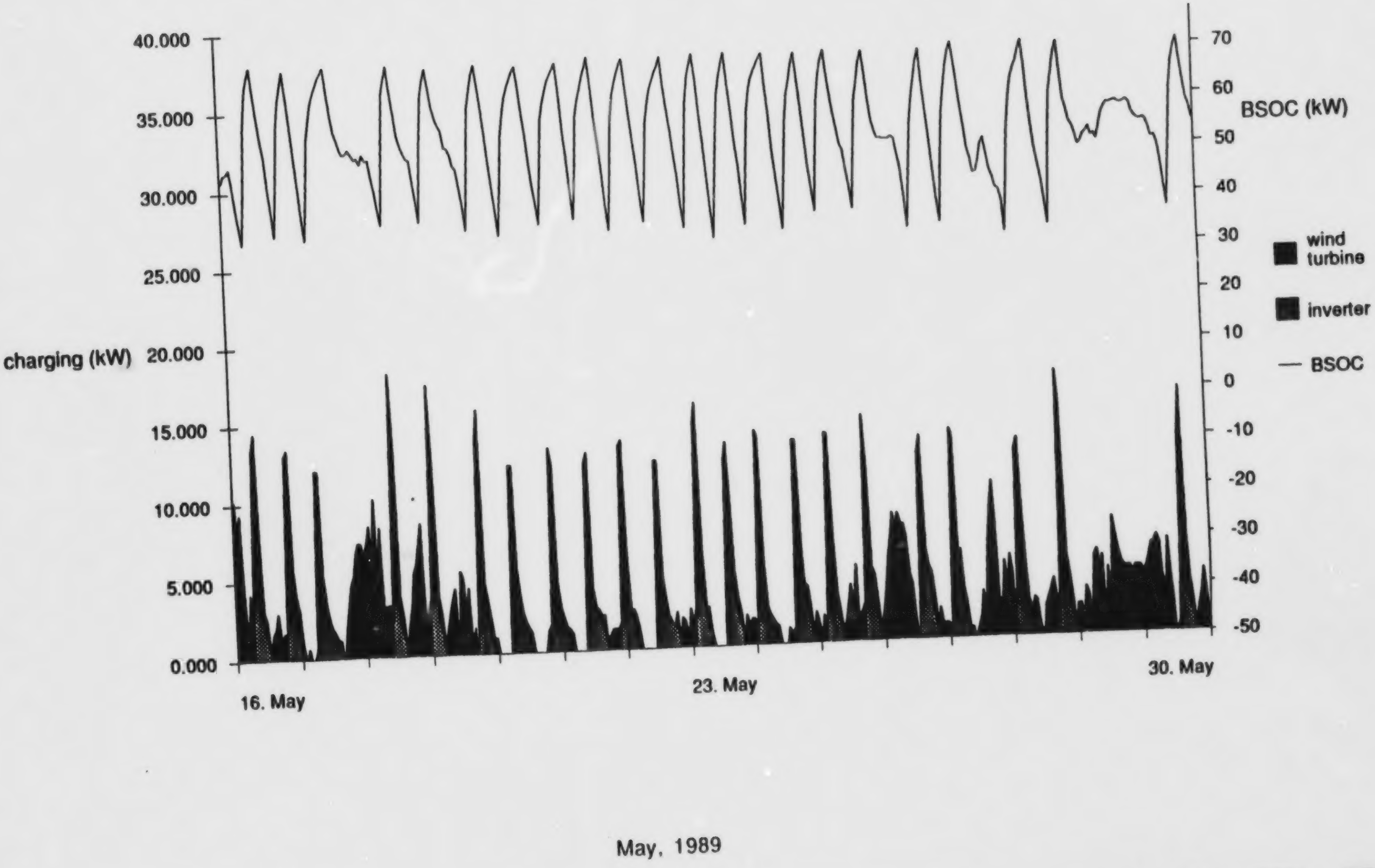
Hindcast Battery Charging History (1. May - 15. May)



May, 1989

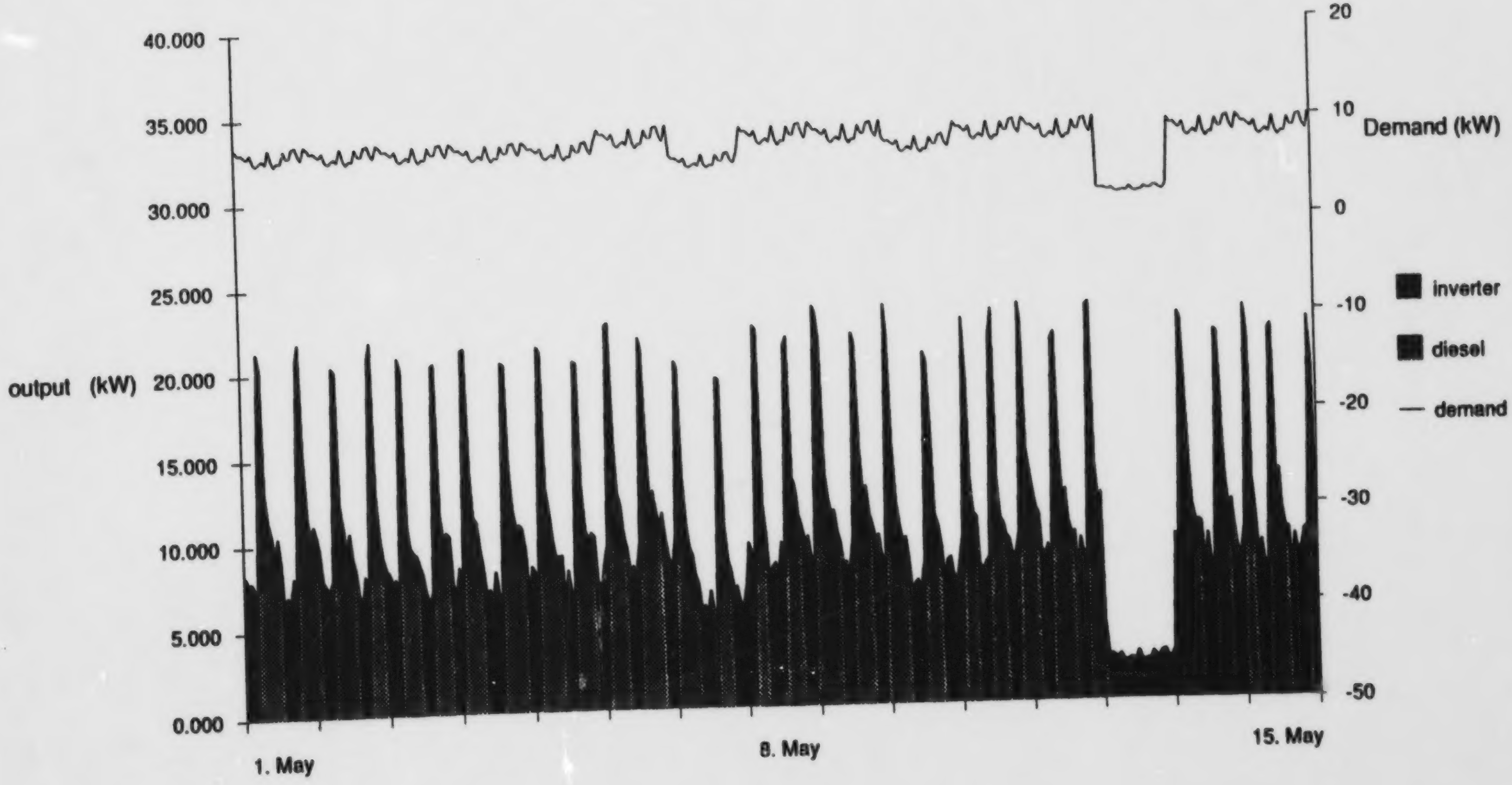
based on 60% of actual loads

Hindcast Battery Charging History (16. May - 30. May)



based on actual loads

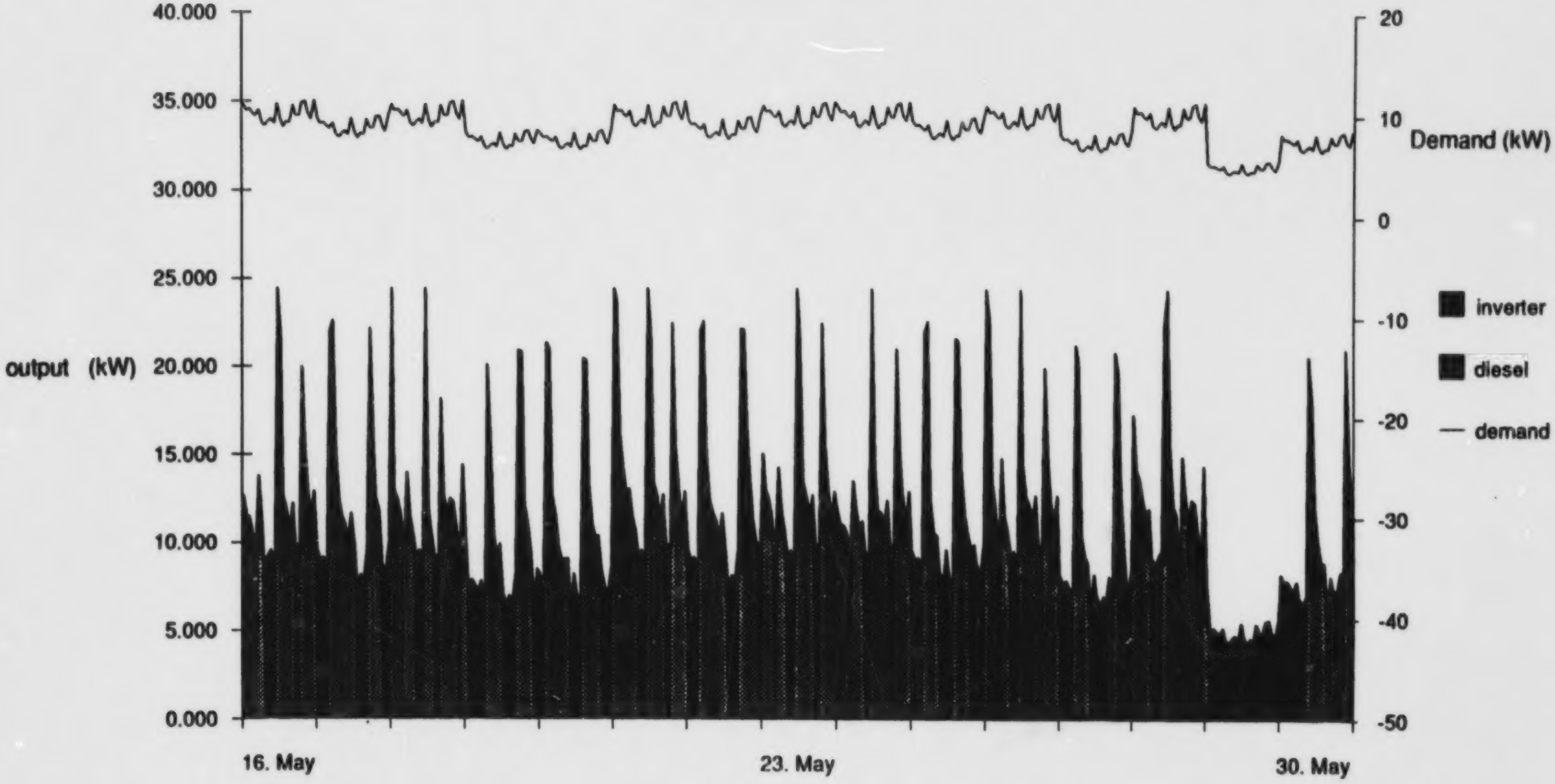
Hindcast Load History (1. May - 15. May)



May, 1989

based on actual loads

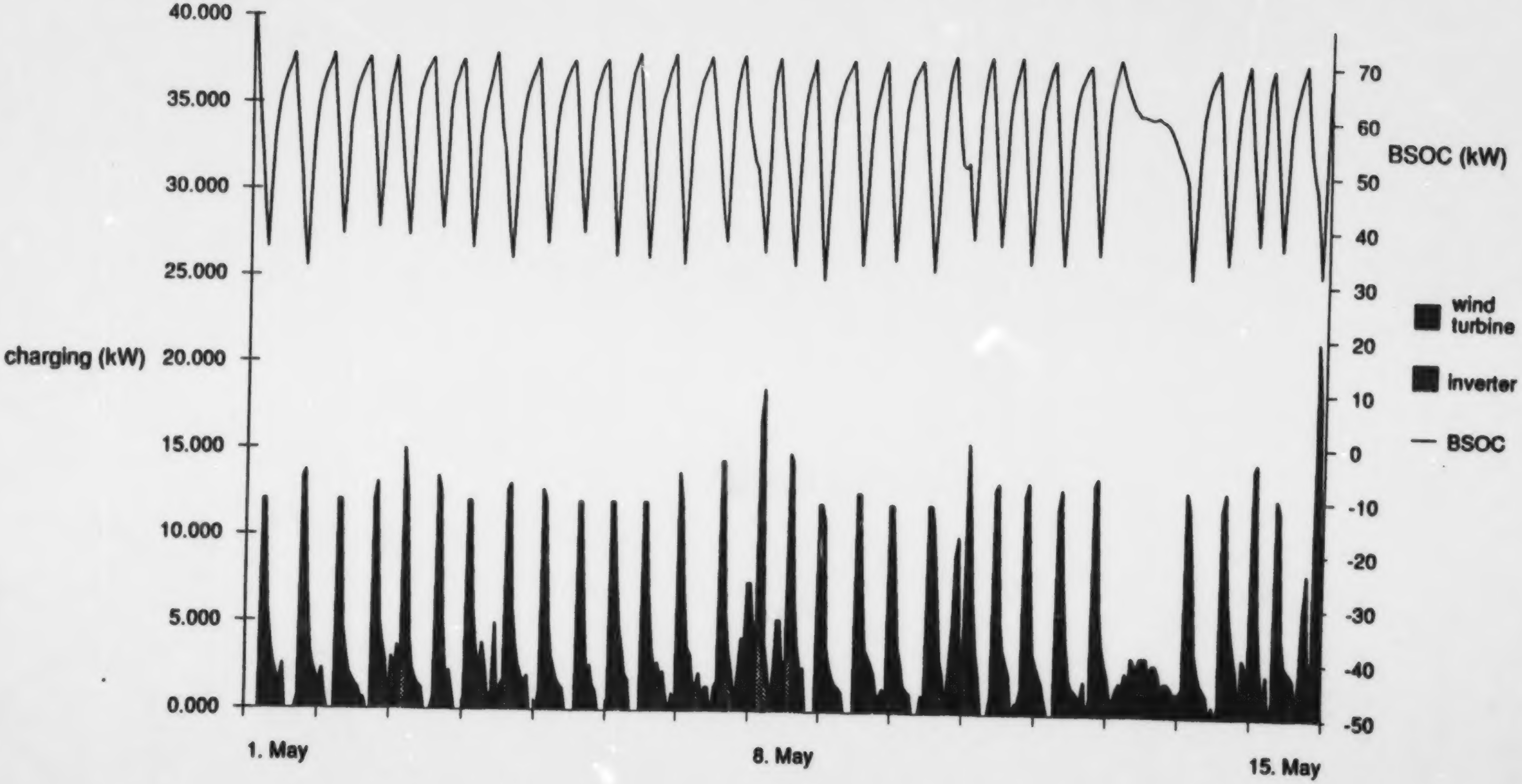
Hindcast Load History (16. May - 30. May)



May, 1989

based on actual loads

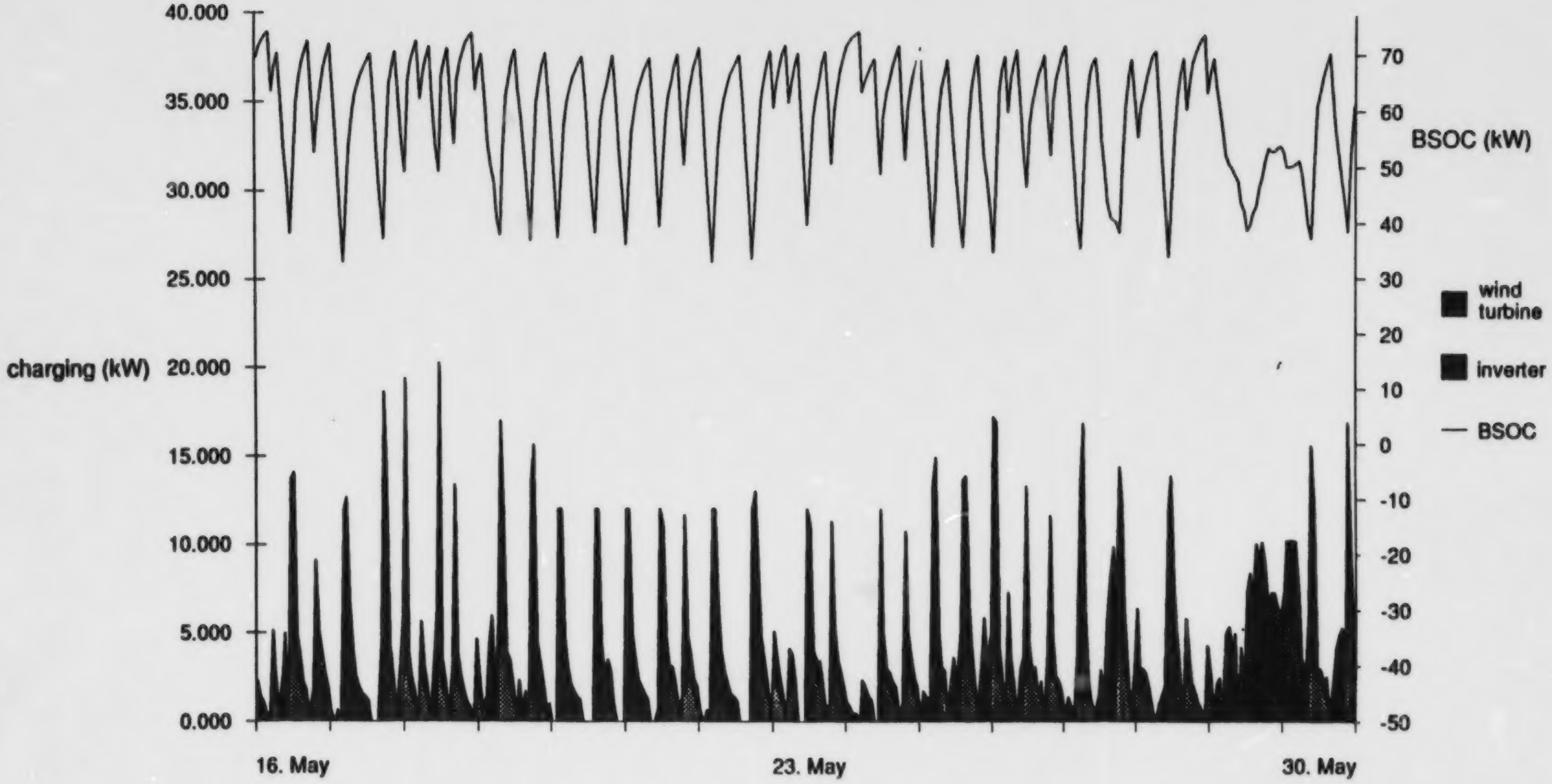
Hindcast Battery Charging History (1. May - 15. May)



May, 1989

based on actual loads

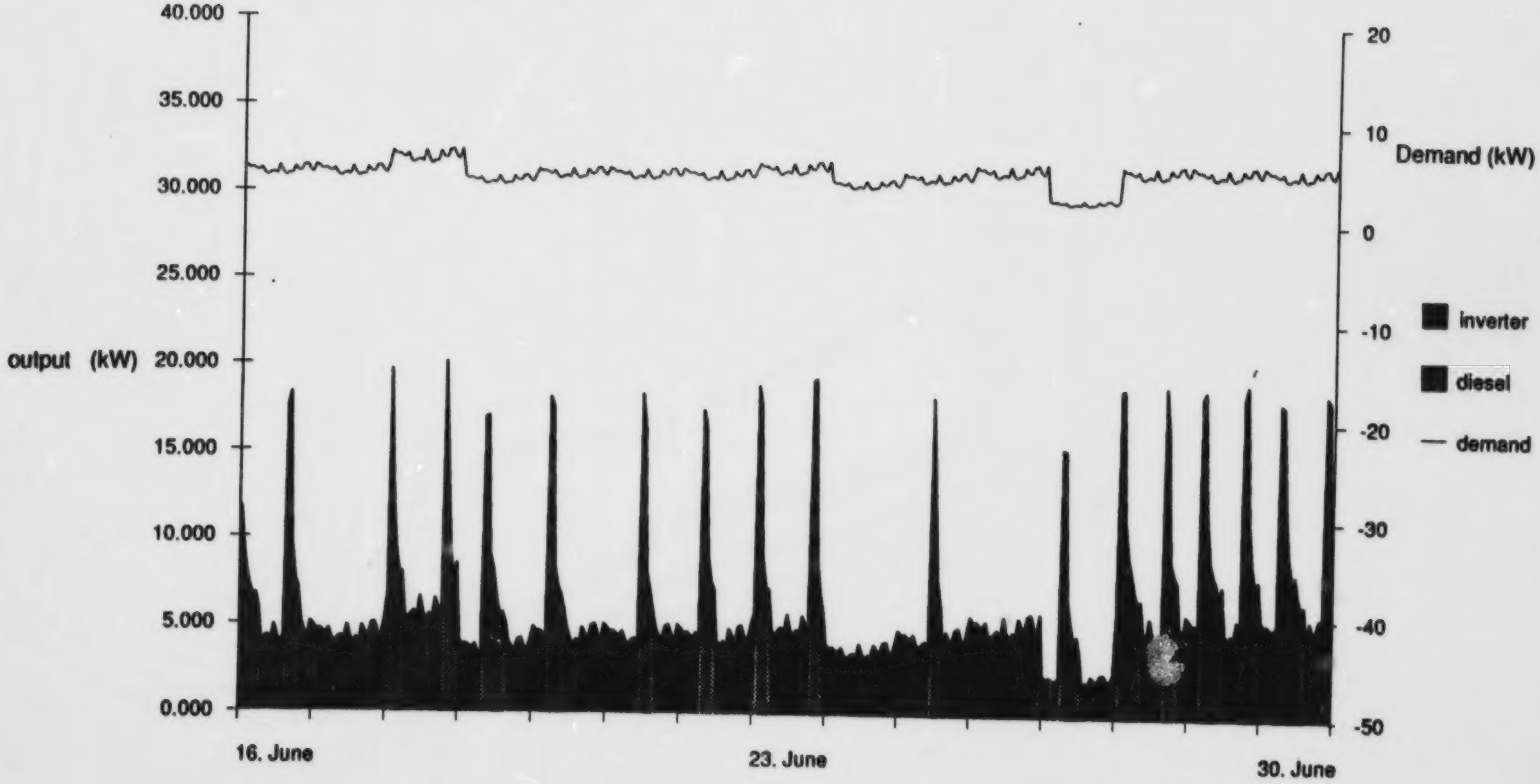
Hindcast Battery Charging History (16. May - 30. May)



May, 1989

based on 60% of actual loads

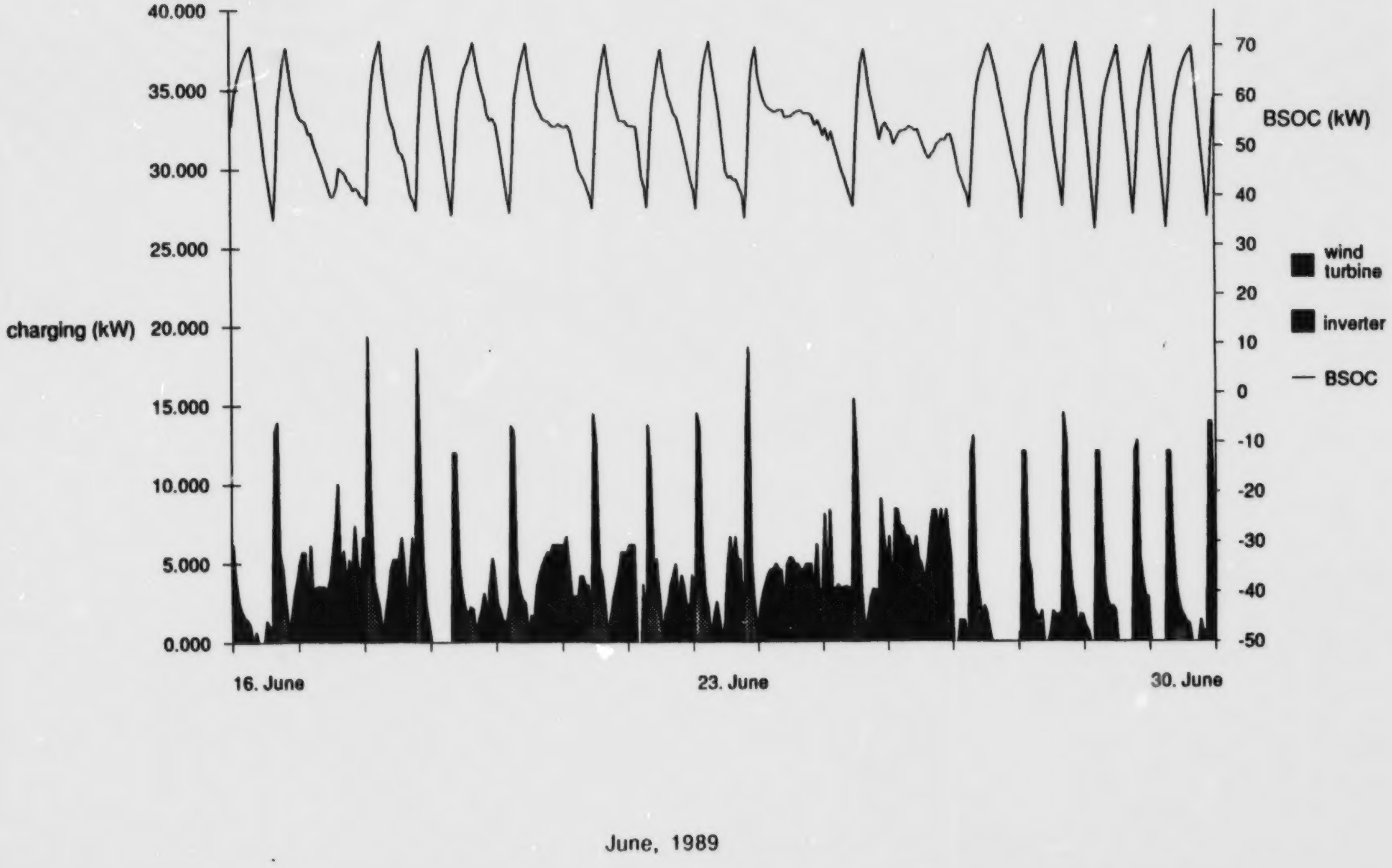
Hindcast Load History (16. June - 30. June)



June, 1989

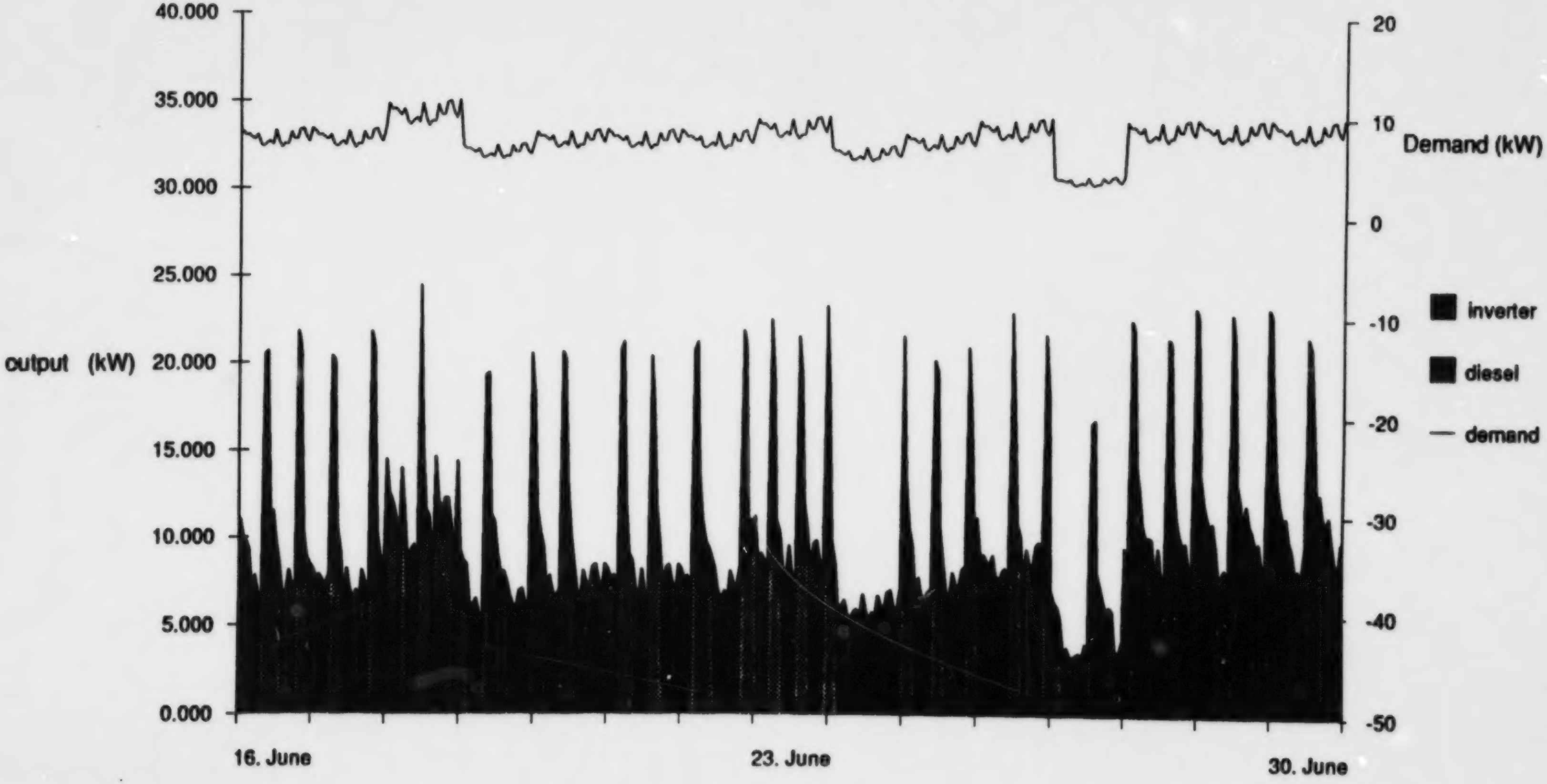
based on 60% of actual loads

Hindcast Battery Charging History (16. June - 30. June)



based on actual loads

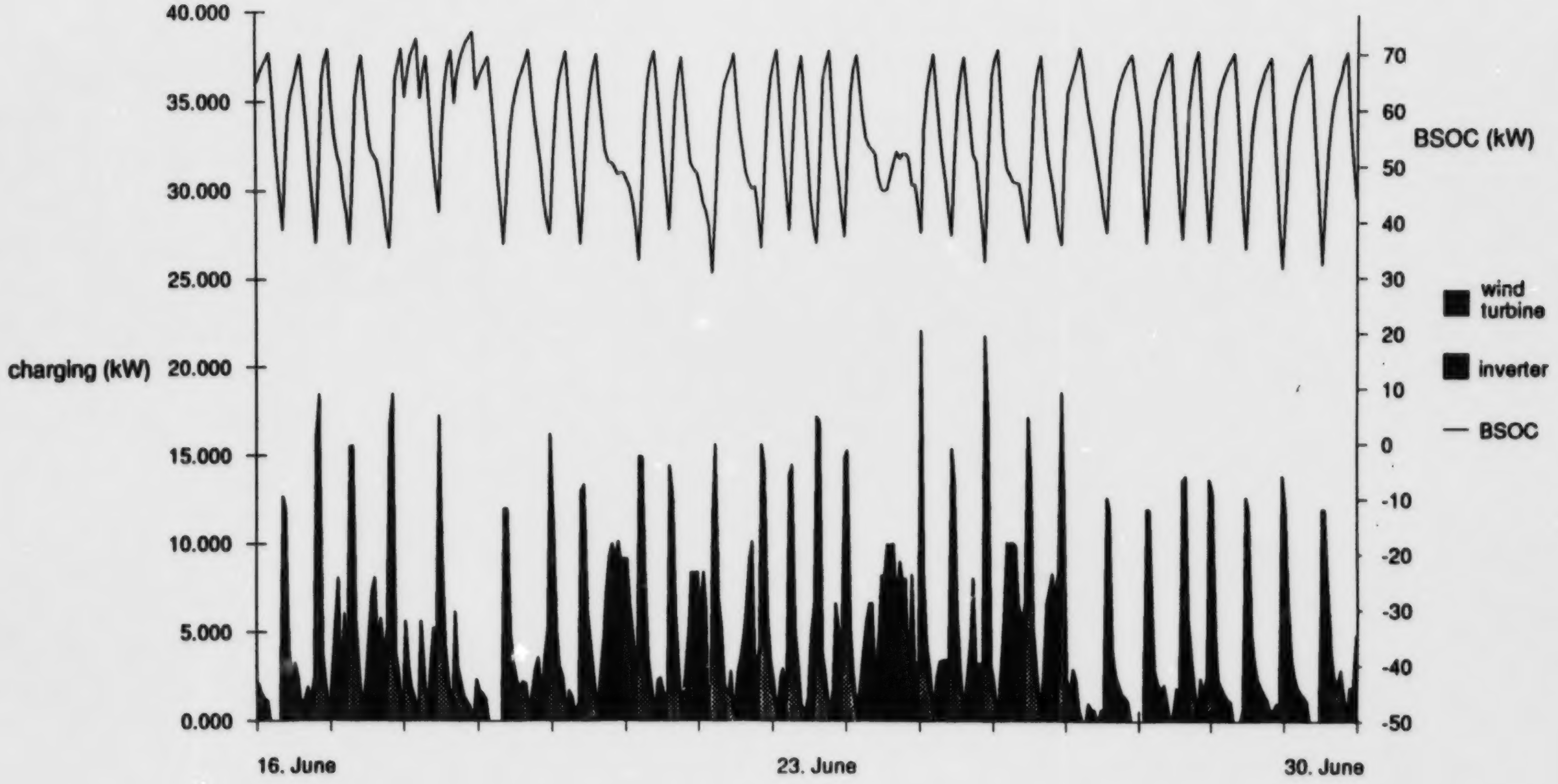
Hindcast Load History (16. June - 30. June)



June, 1989

based on actual loads

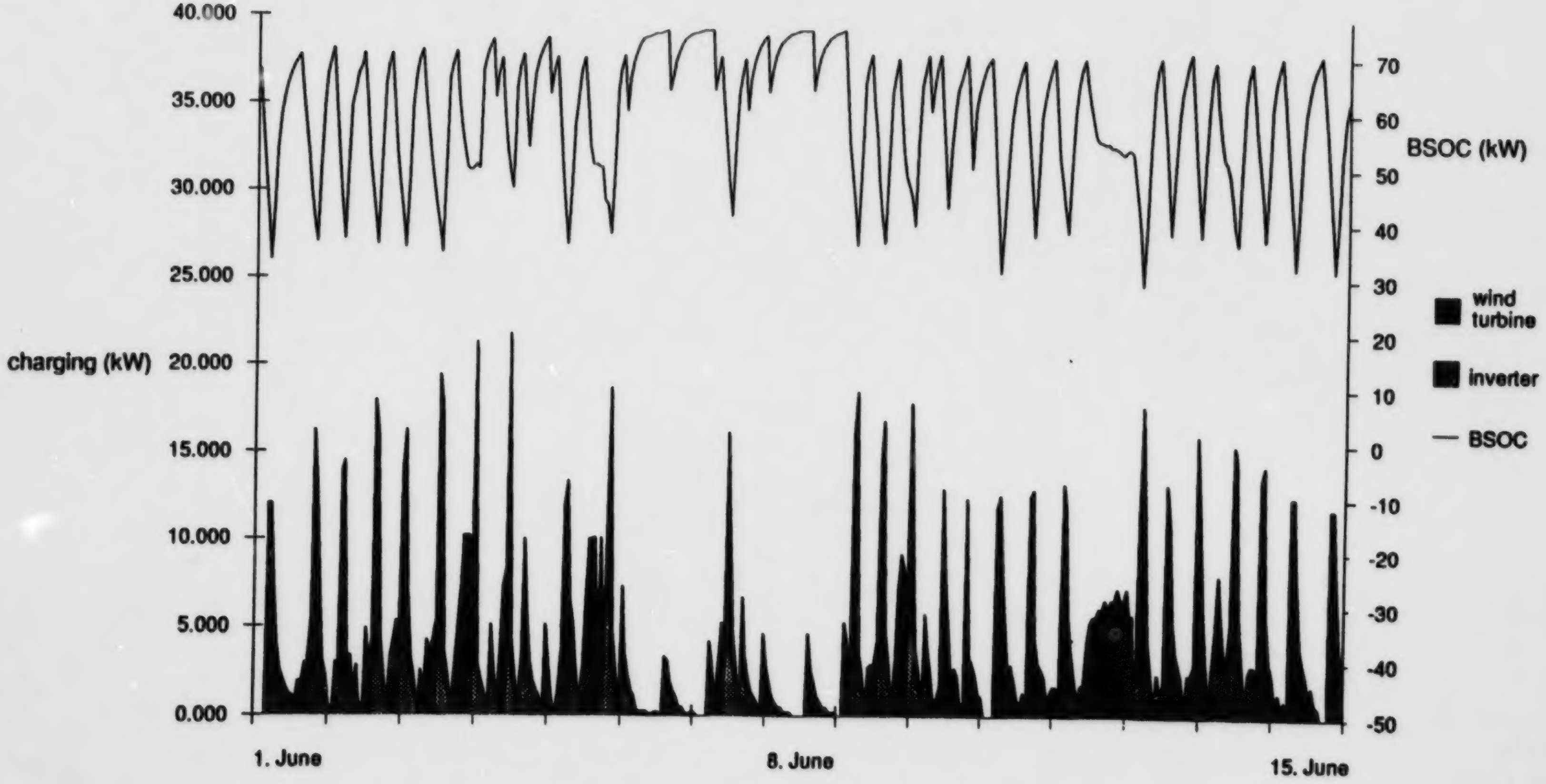
Hindcast Battery Charging History (16. June - 30. June)



June, 1989

based on actual loads

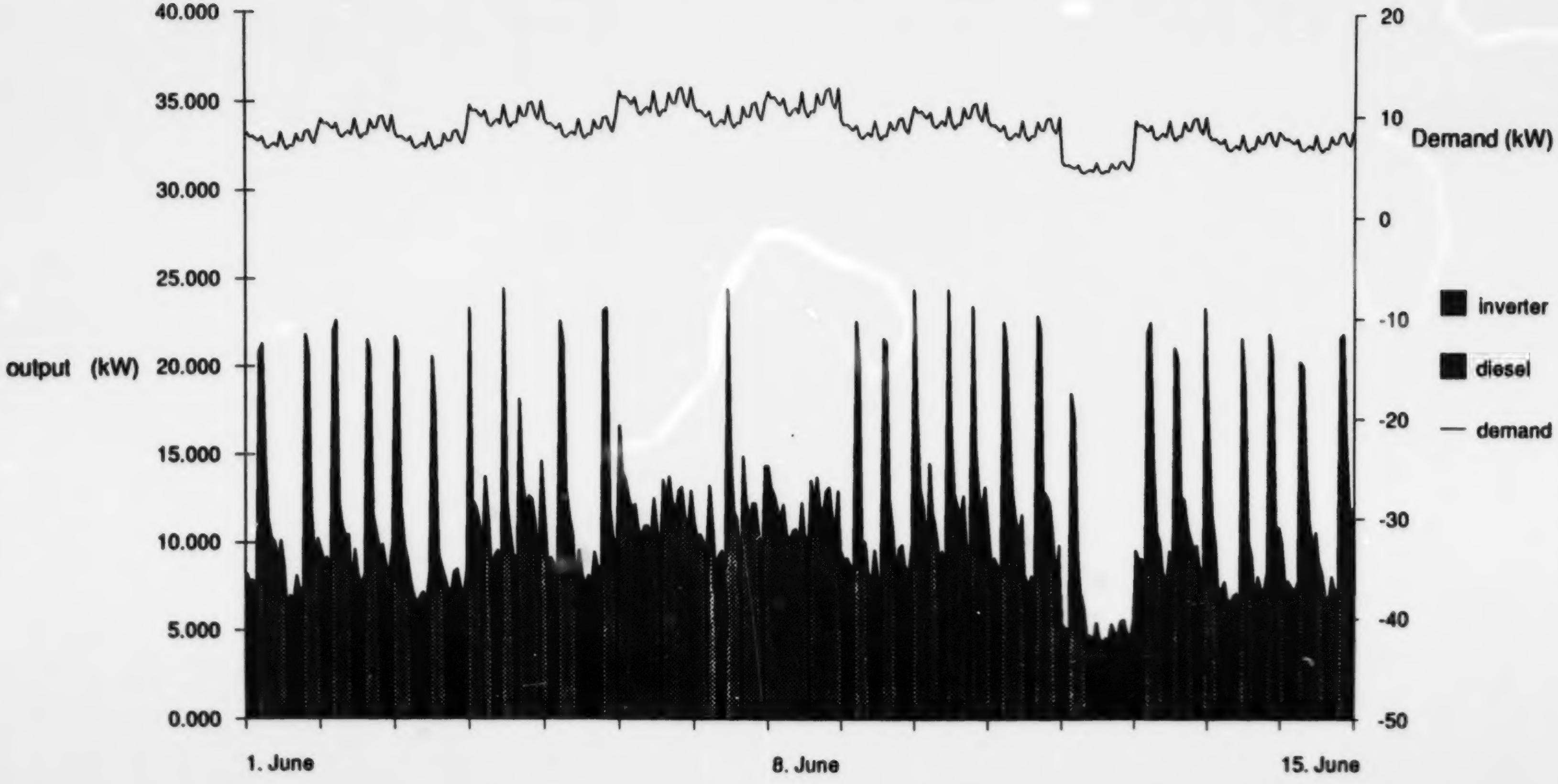
Hindcast Battery Charging History (1. June - 15. June)



June, 1989

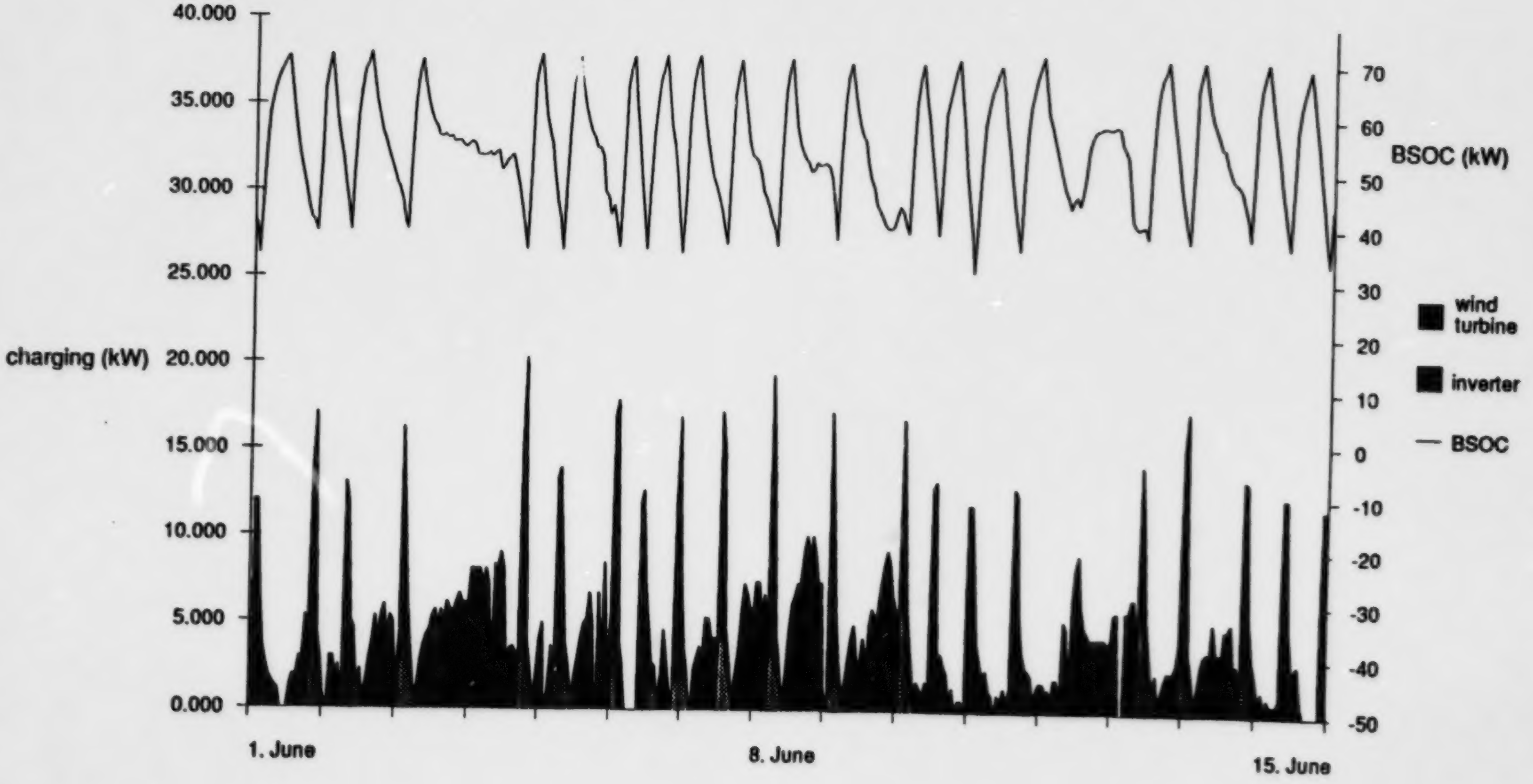
based on actual loads

Hindcast Load History (1. June - 15. June)



June, 1989

based on 60% of actual loads

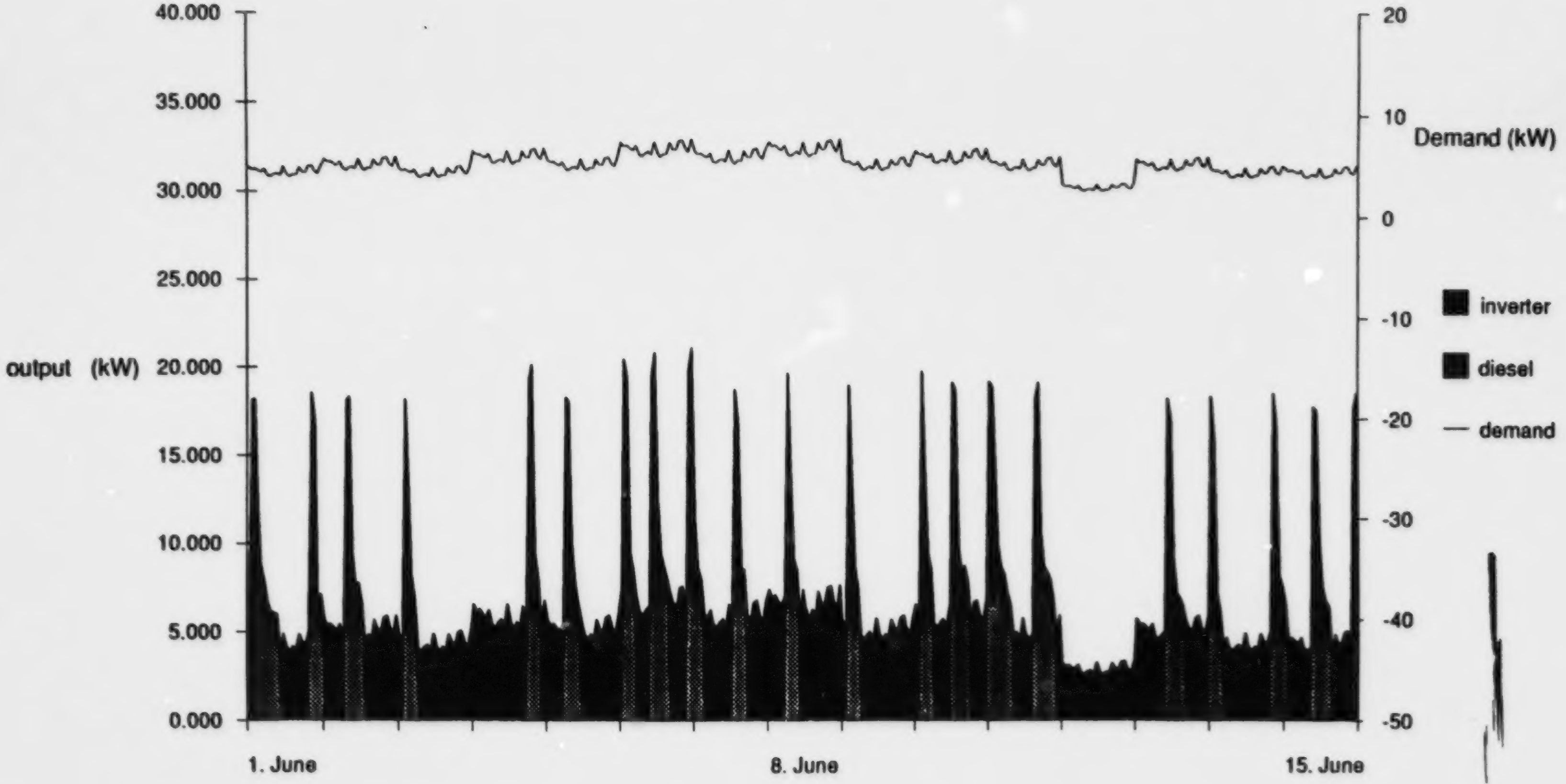


Hindcast Battery Charging History (1. June - 15. June)

June, 1989

based on 60% of actual loads

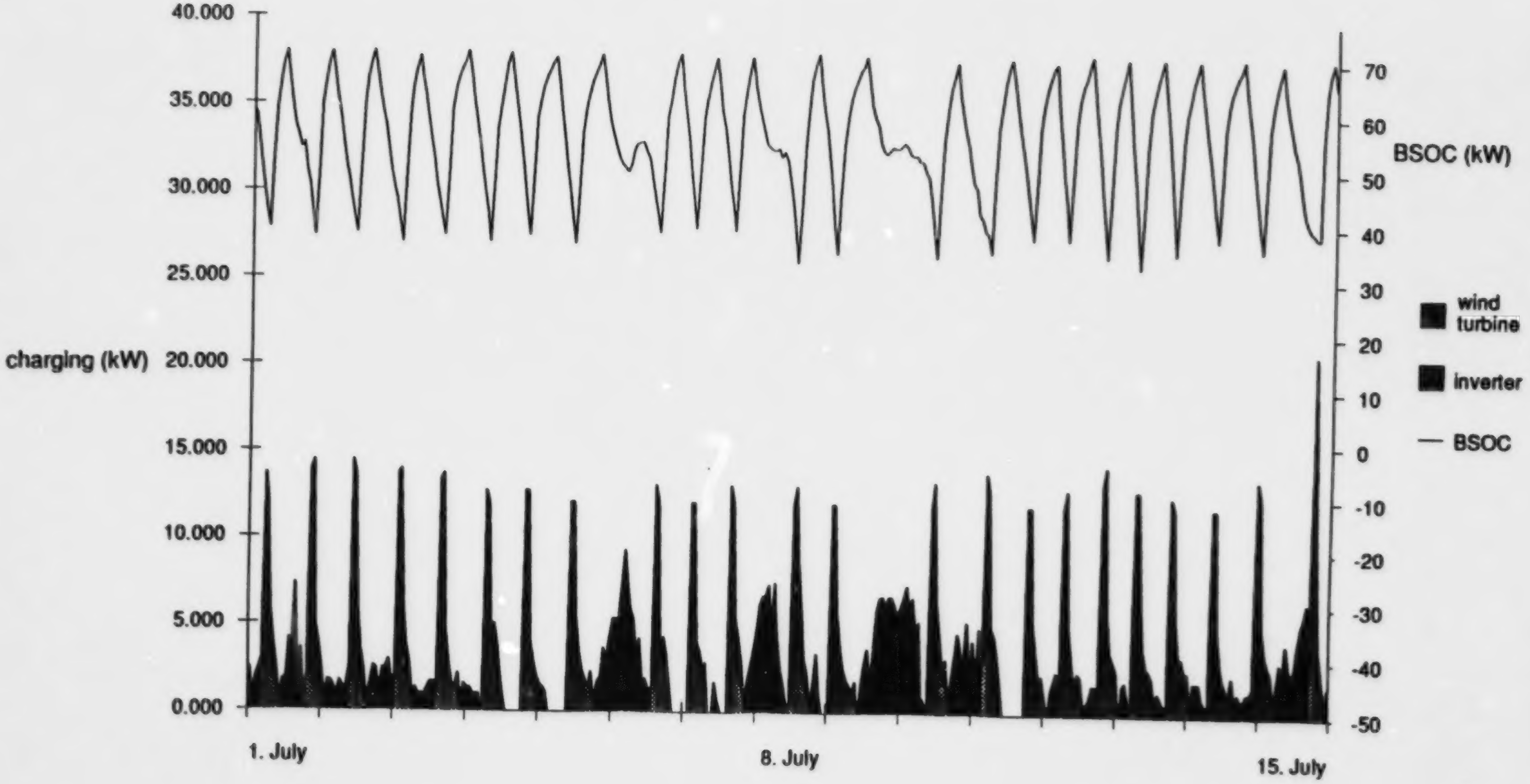
Hindcast Load History (1. June - 15. June)



June, 1989

based on 60% of actual loads

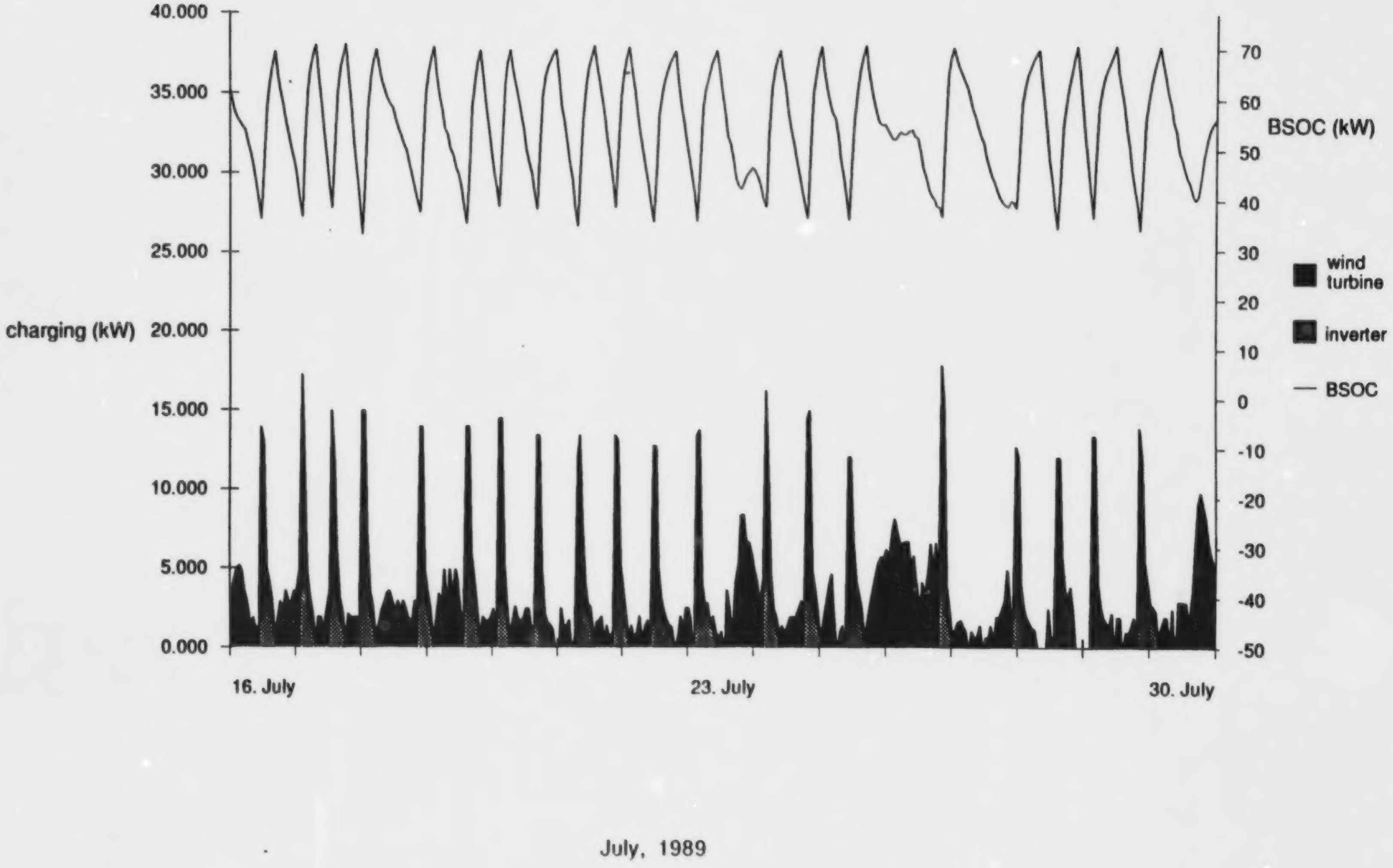
Hindcast Battery Charging History (1. July - 15. July)



July, 1989

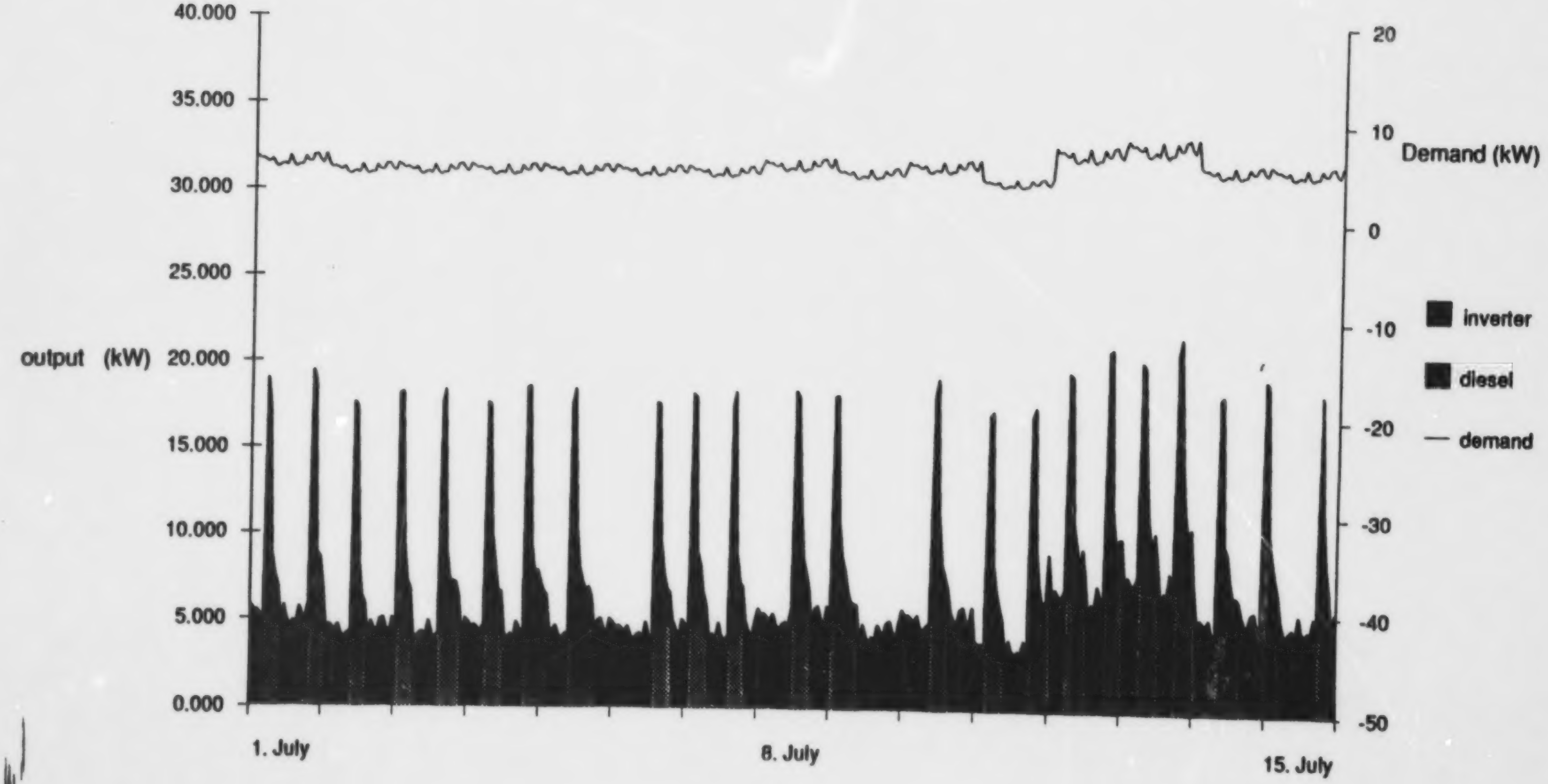
based on 60% of actual loads

Hindcast Battery Charging History (16. July - 30. July)



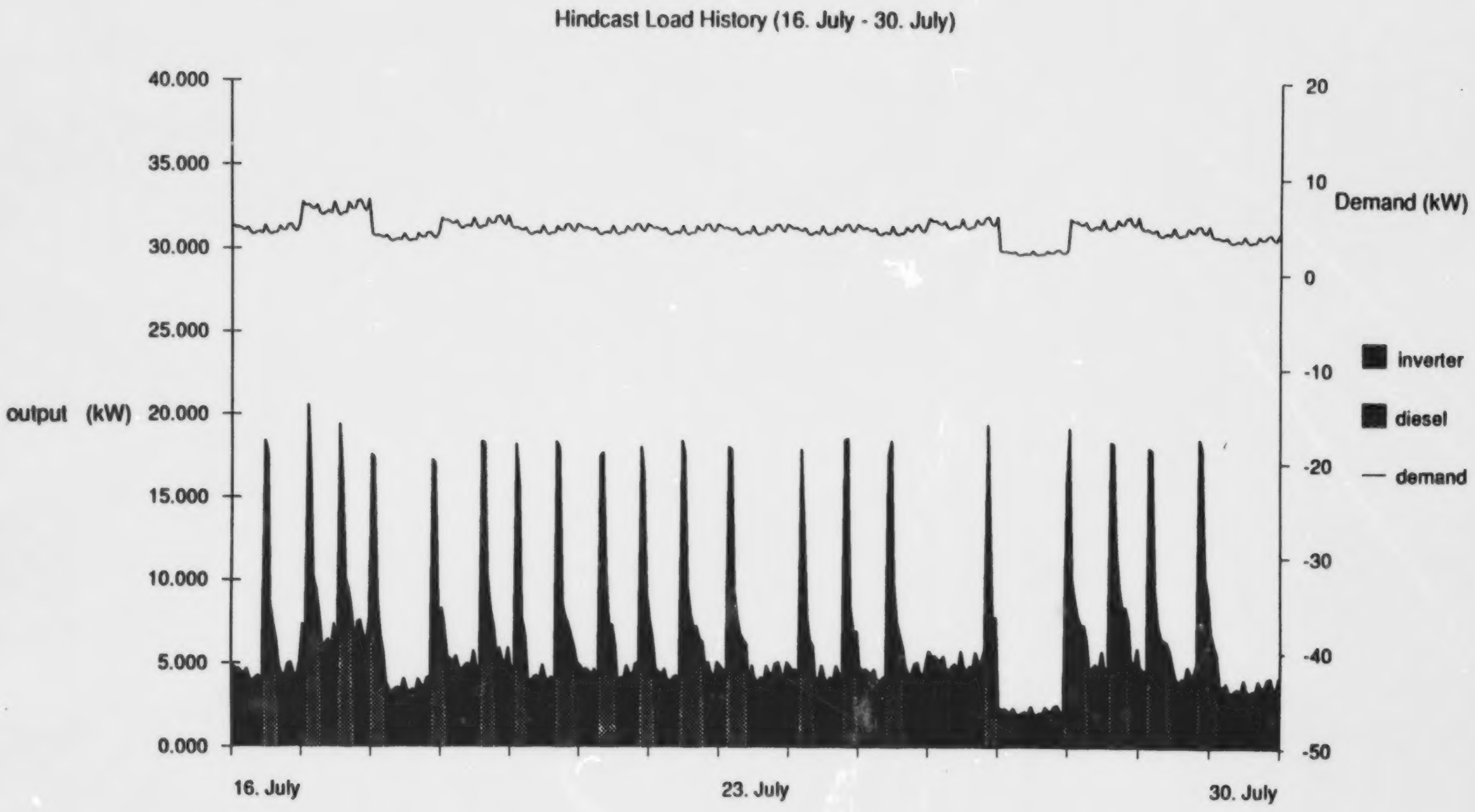
based on 60% of actual load

Hindcast Load History (1. July - 15. July)



July, 1989

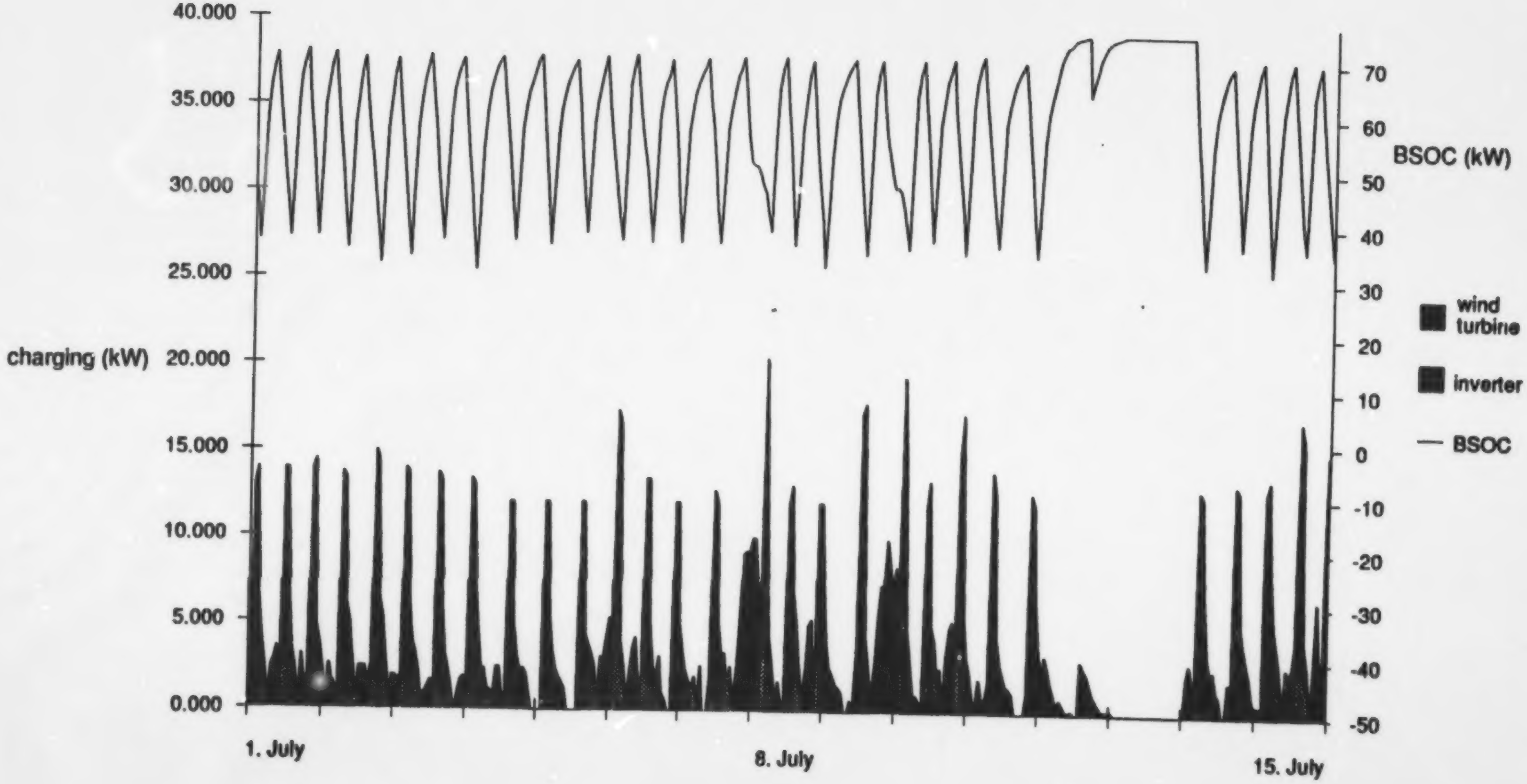
based on 60% of actual loads



July, 1989

based on actual loads

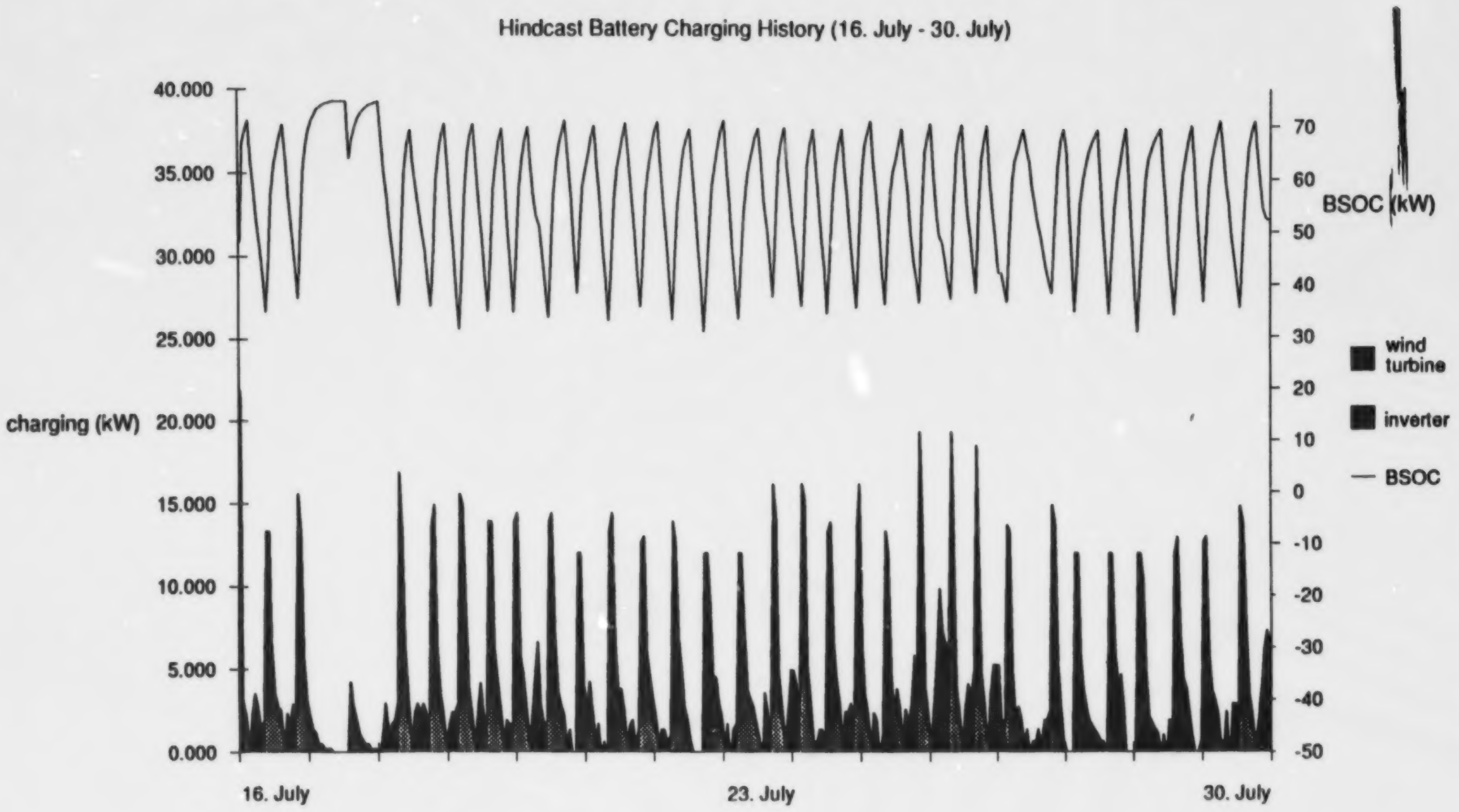
Hindcast Battery Charging History (1. July - 15. July)



July, 1989

based on actual loads

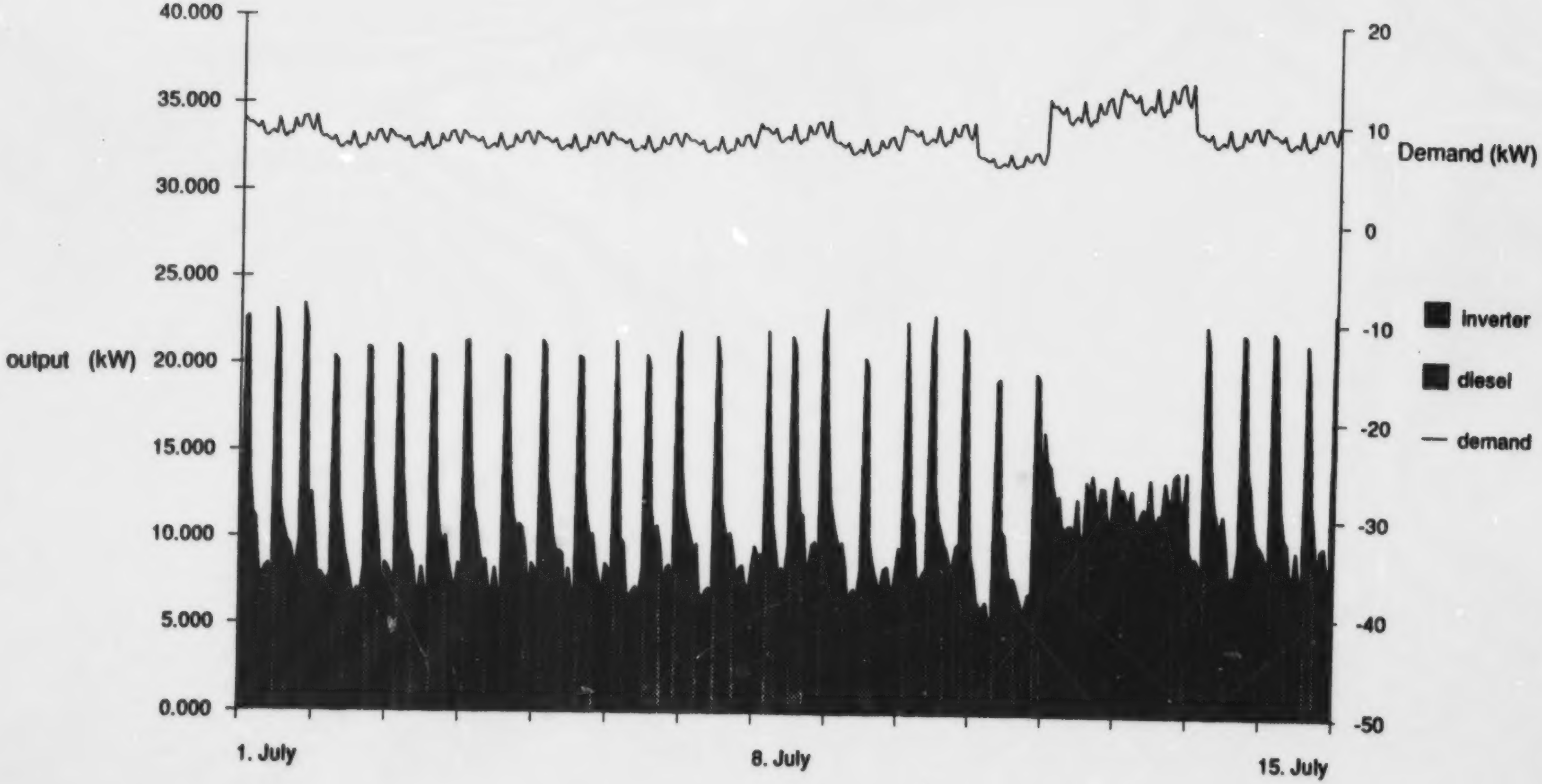
Hindcast Battery Charging History (16. July - 30. July)



July, 1989

based on actual loads

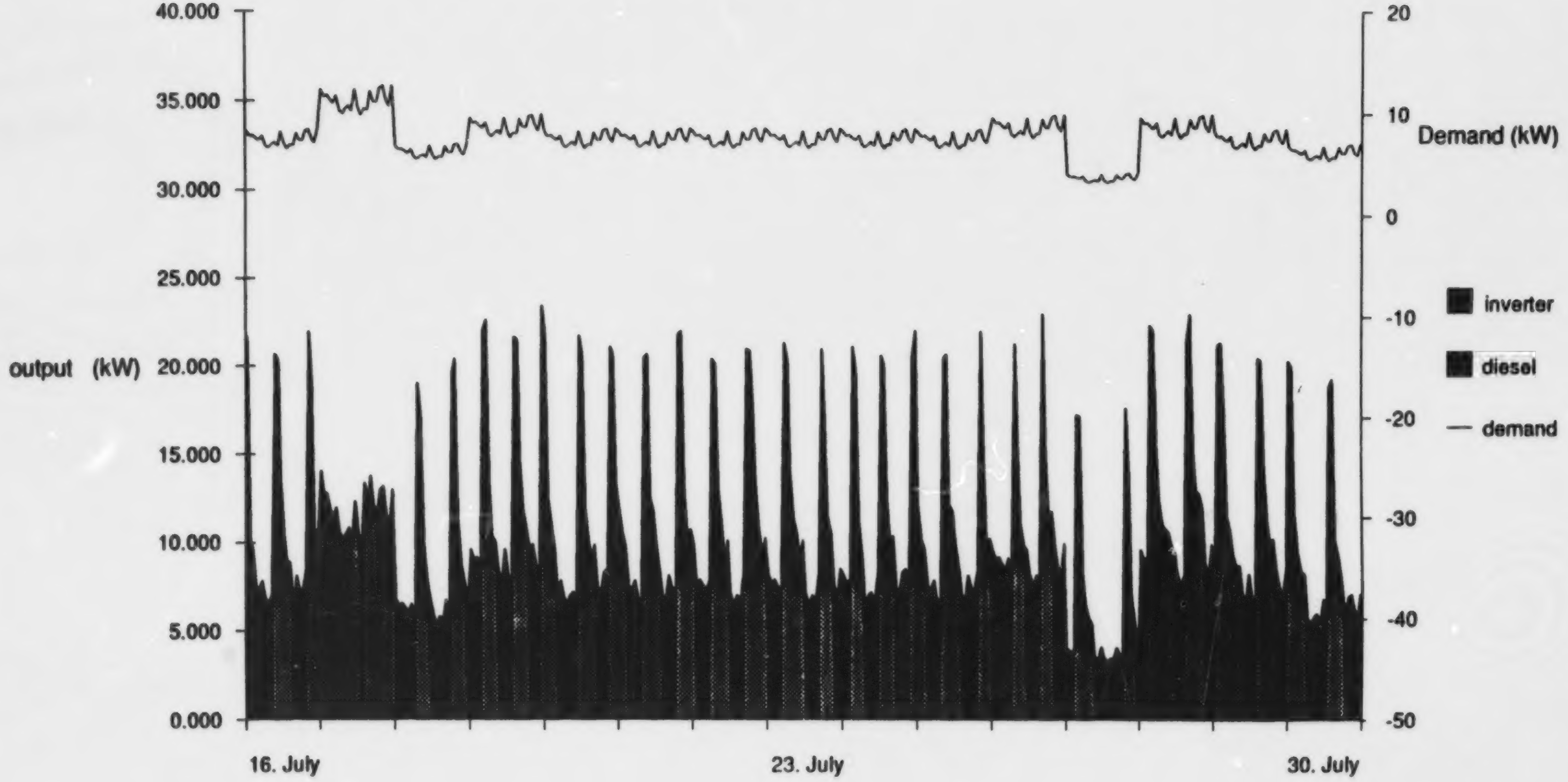
Hindcast Load History (1. July - 15. July)



July, 1989

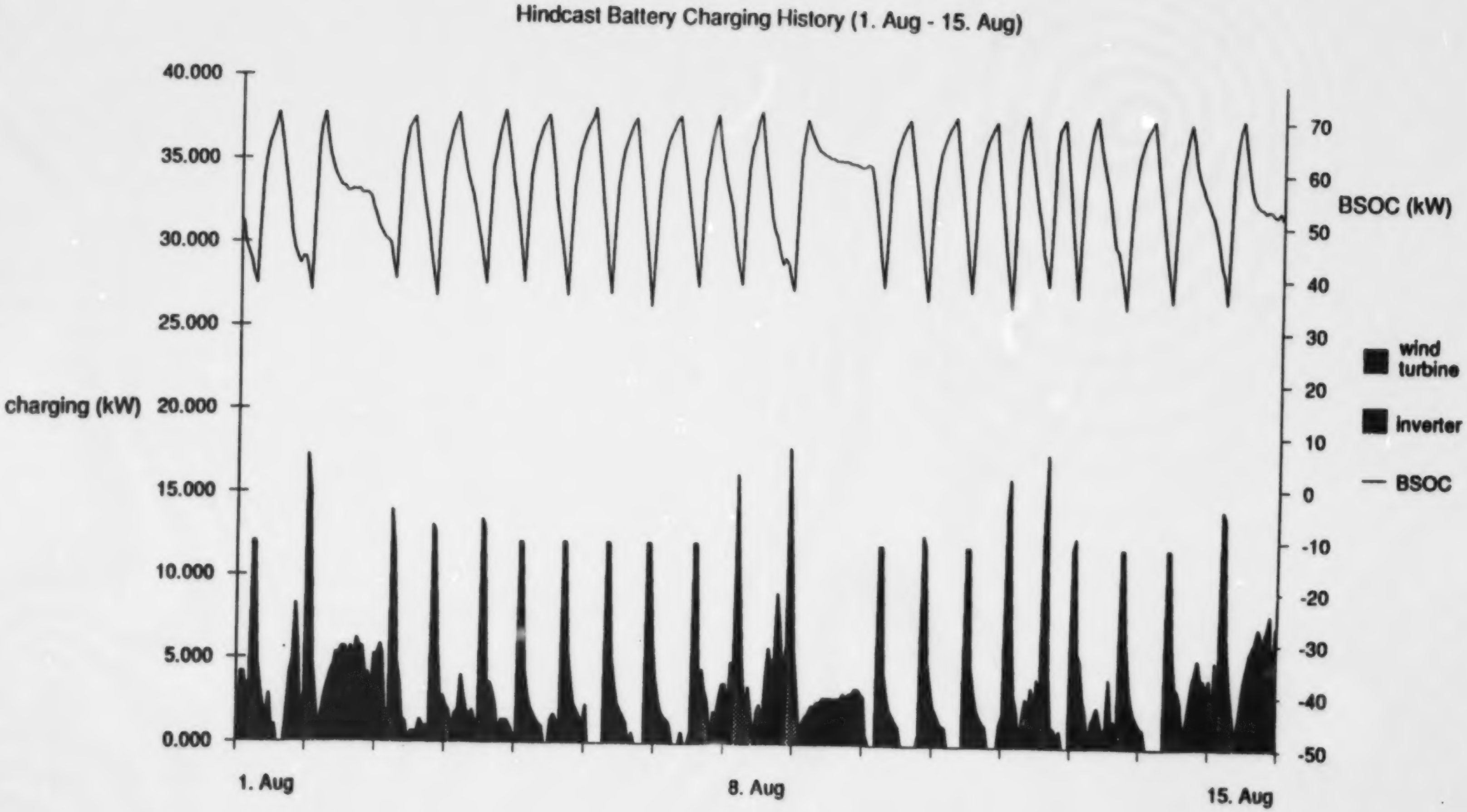
based on actual loads

Hindcast Load History (16. July - 30. July)



July, 1989

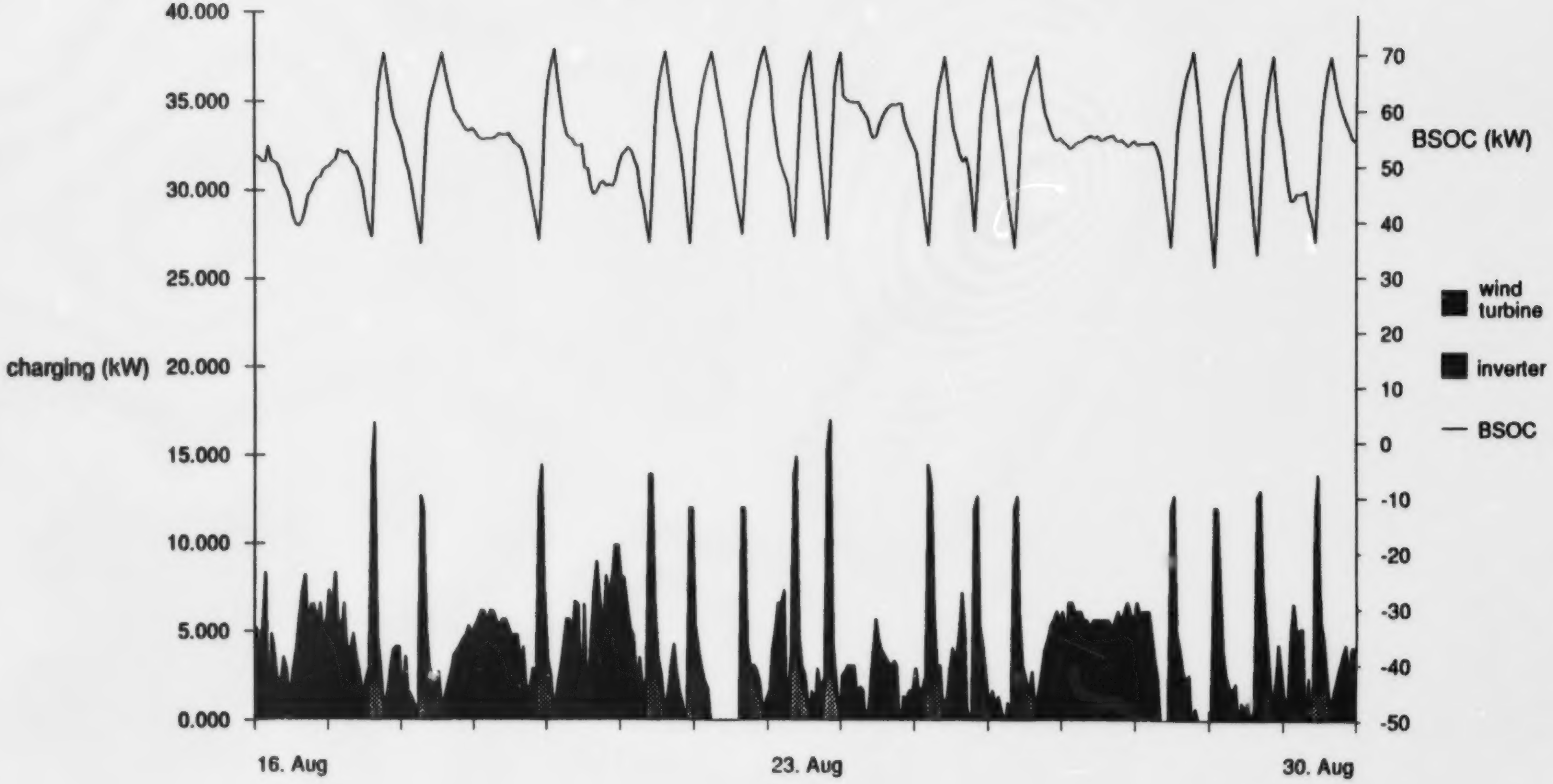
based on 60% of actual loads



August, 1989

based on 60% of actual loads

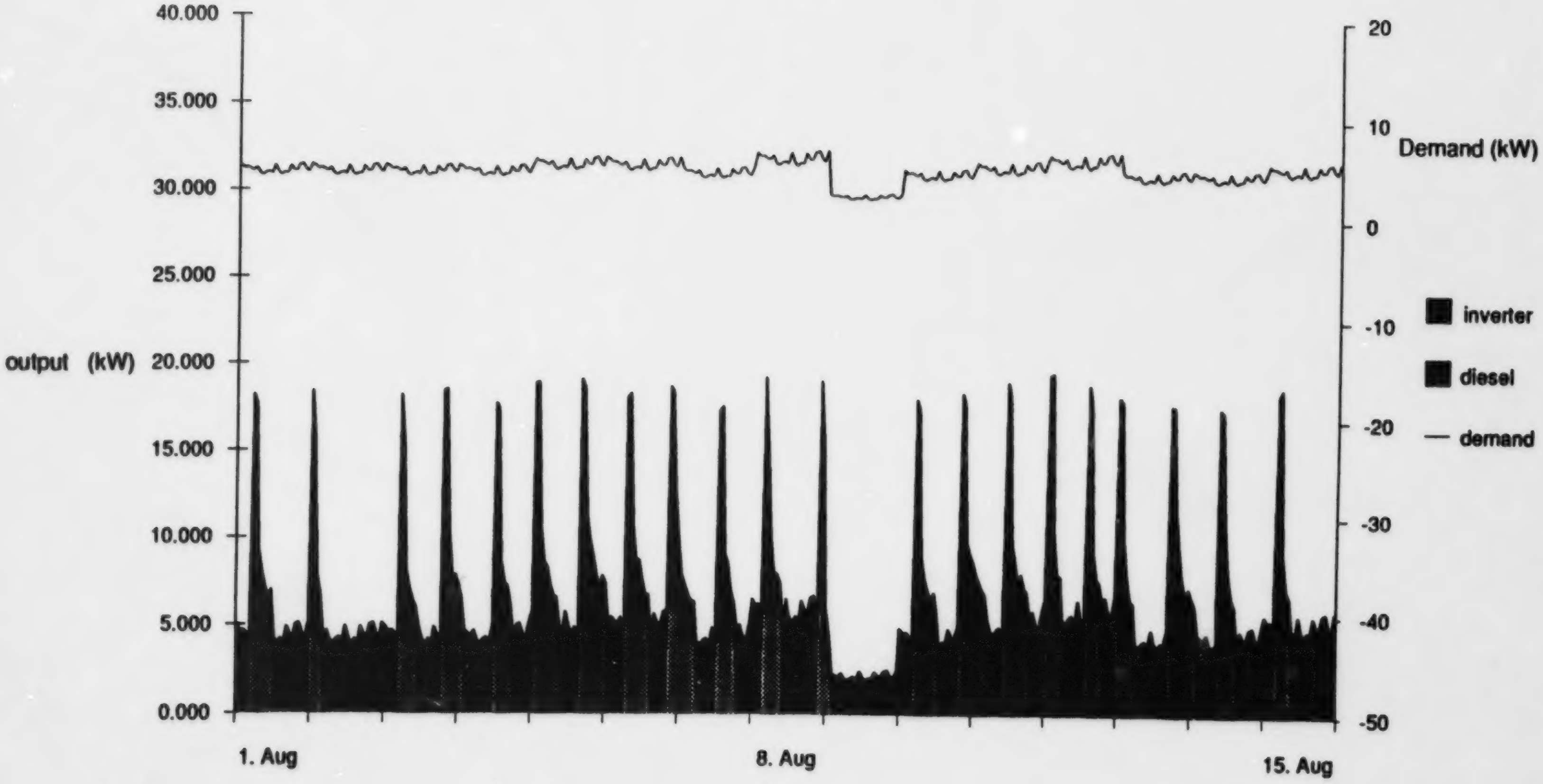
Hindcast Battery Charging History (16. Aug - 30. Aug)



August, 1989

based on 60% of actual loads

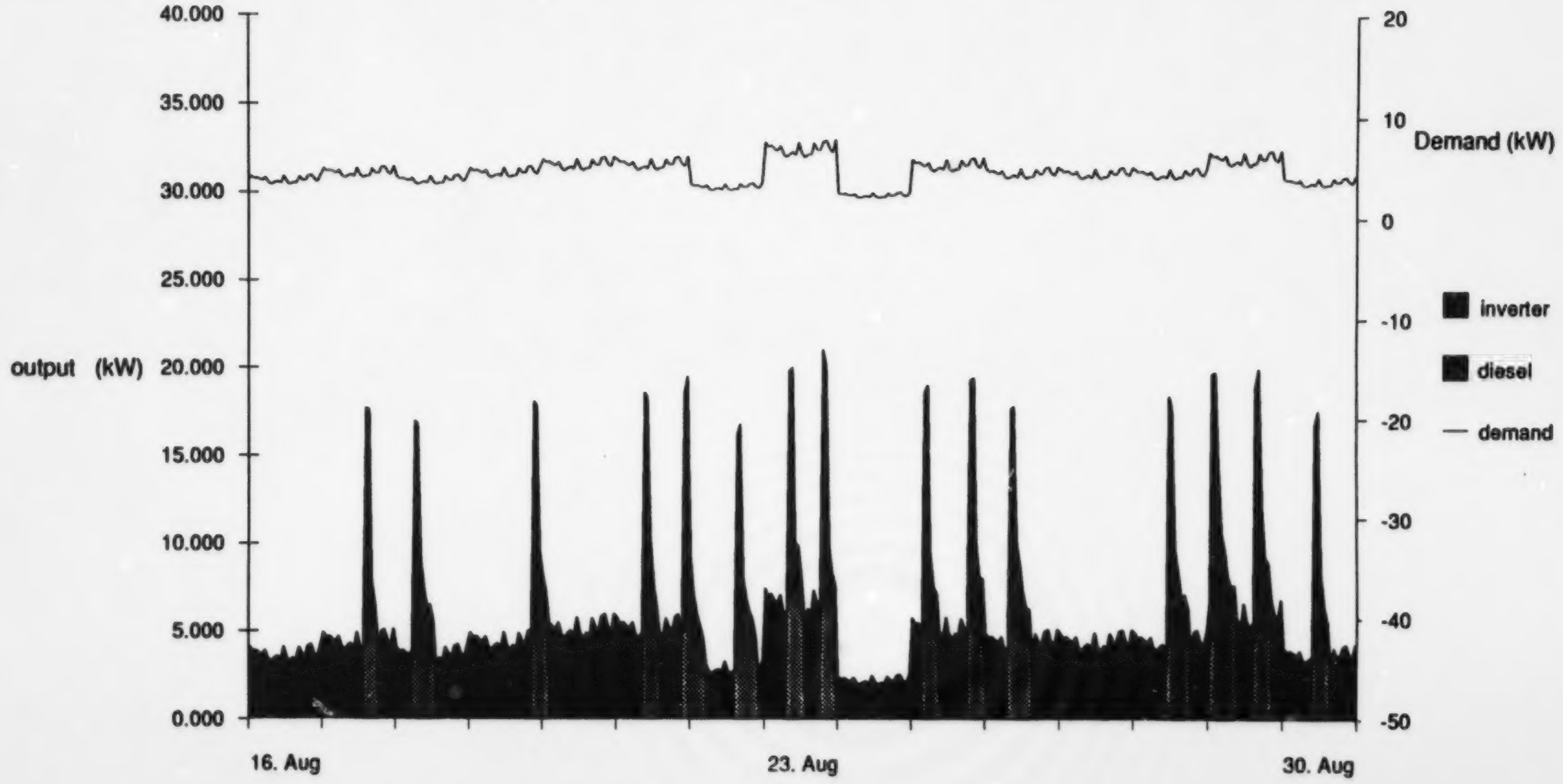
Hindcast Load History (1. Aug - 15. Aug)



August, 1989

based on 60% of actual loads

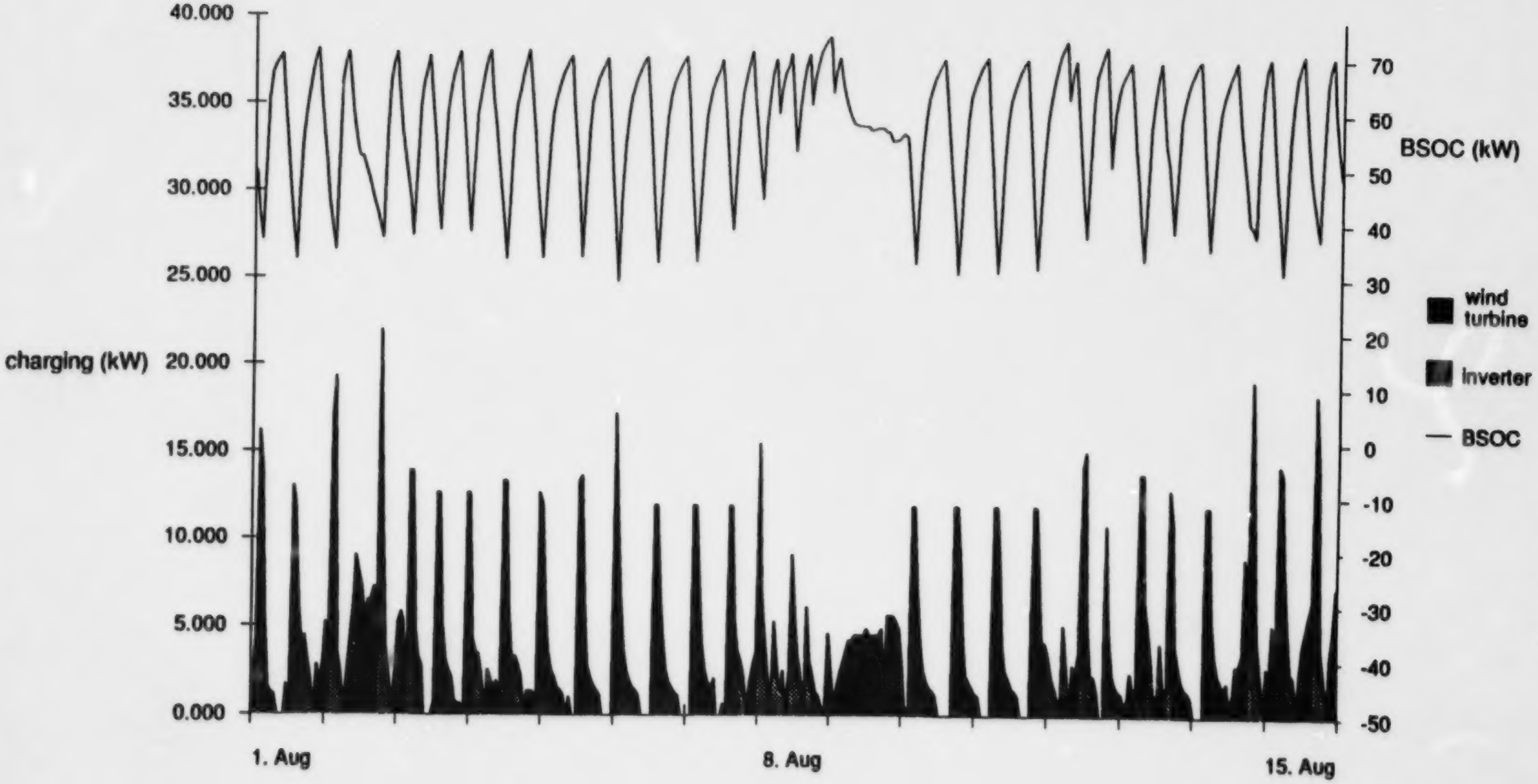
Hindcast Load History (16. Aug - 30. Aug)



August, 1989

based on actual loads

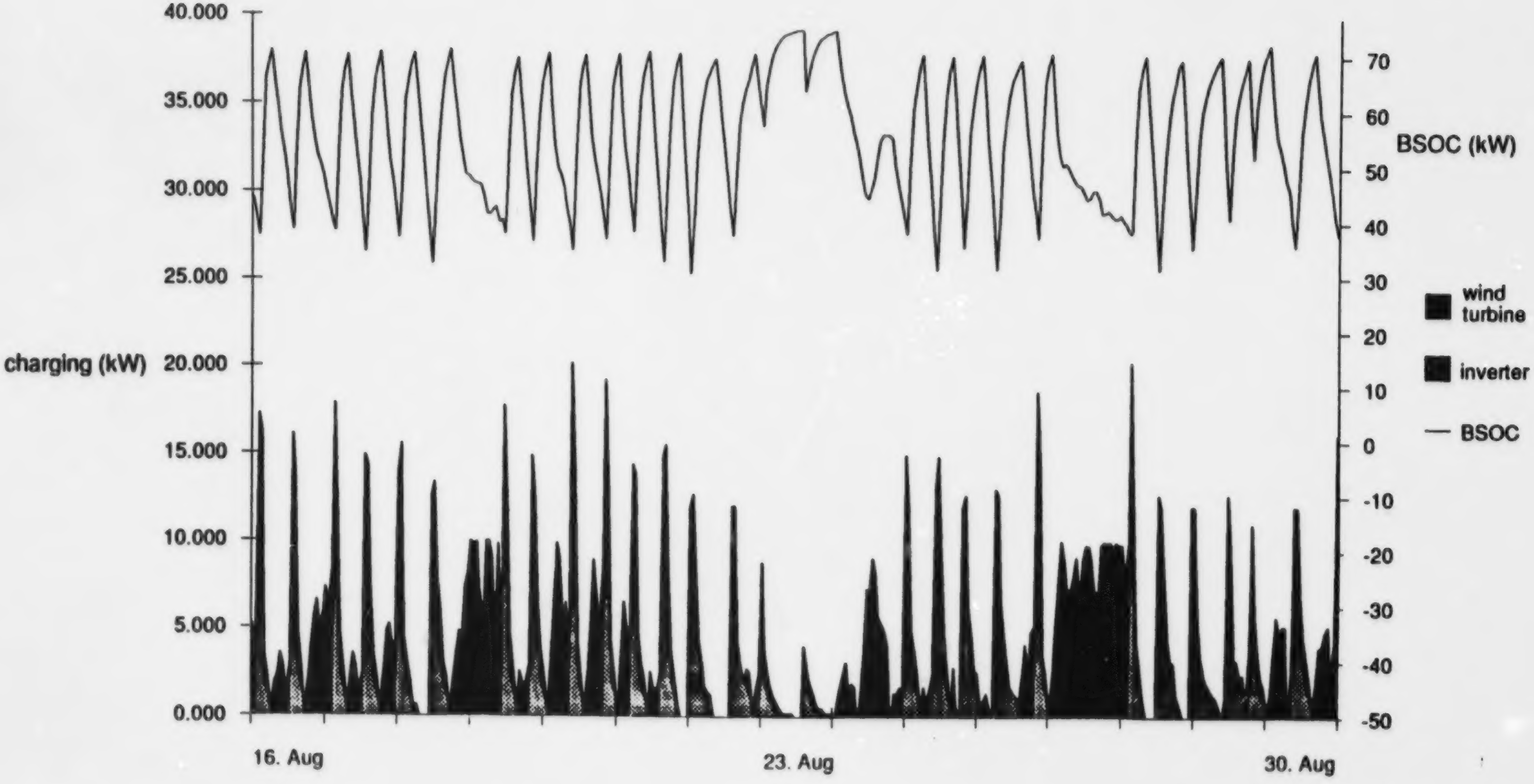
Hindcast Battery Charging History (1. Aug - 15. Aug)



August, 1989

based on actual loads

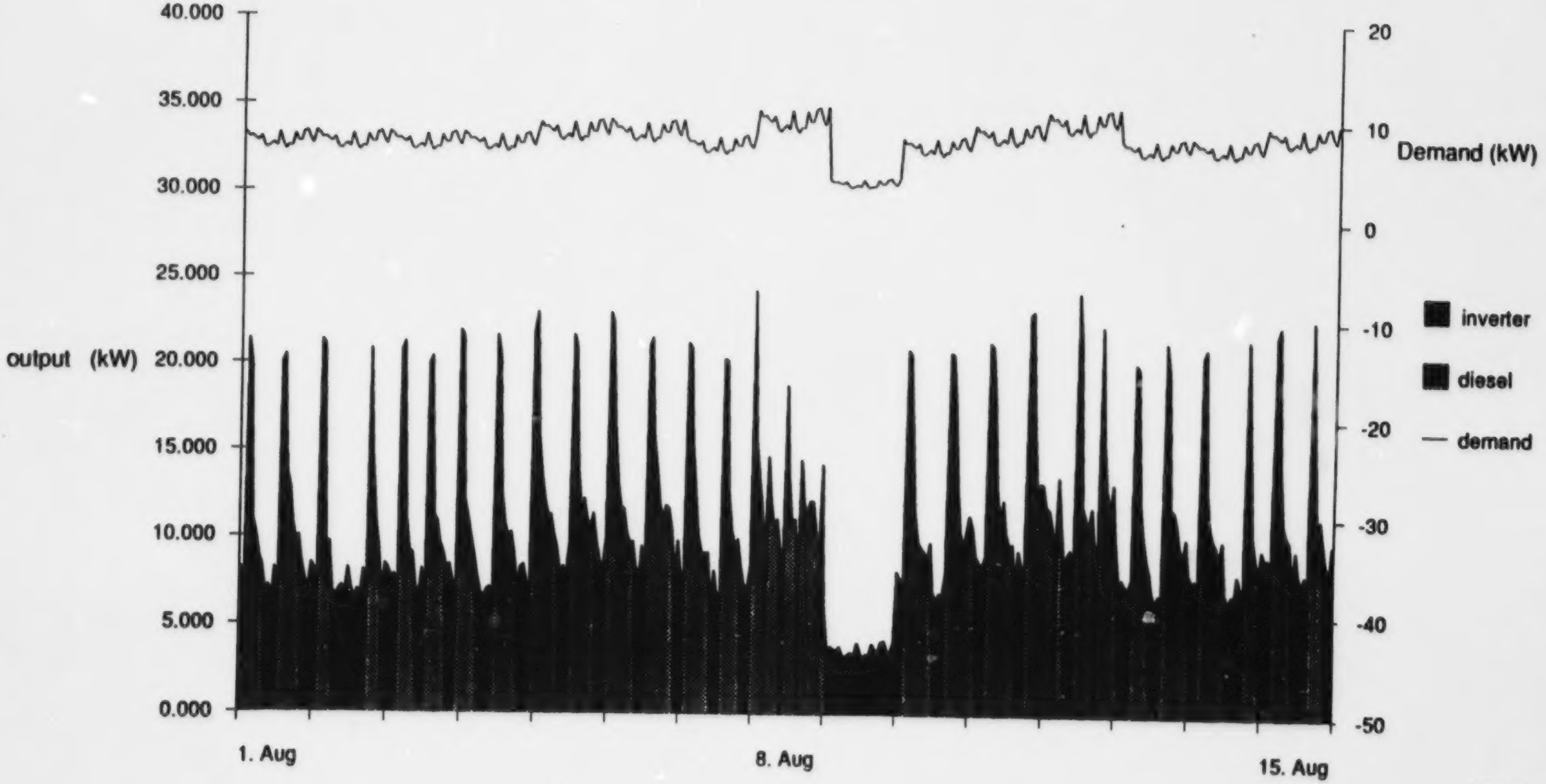
Hindcast Battery Charging History (16. Aug - 30. Aug)



August, 1989

based on actual loads

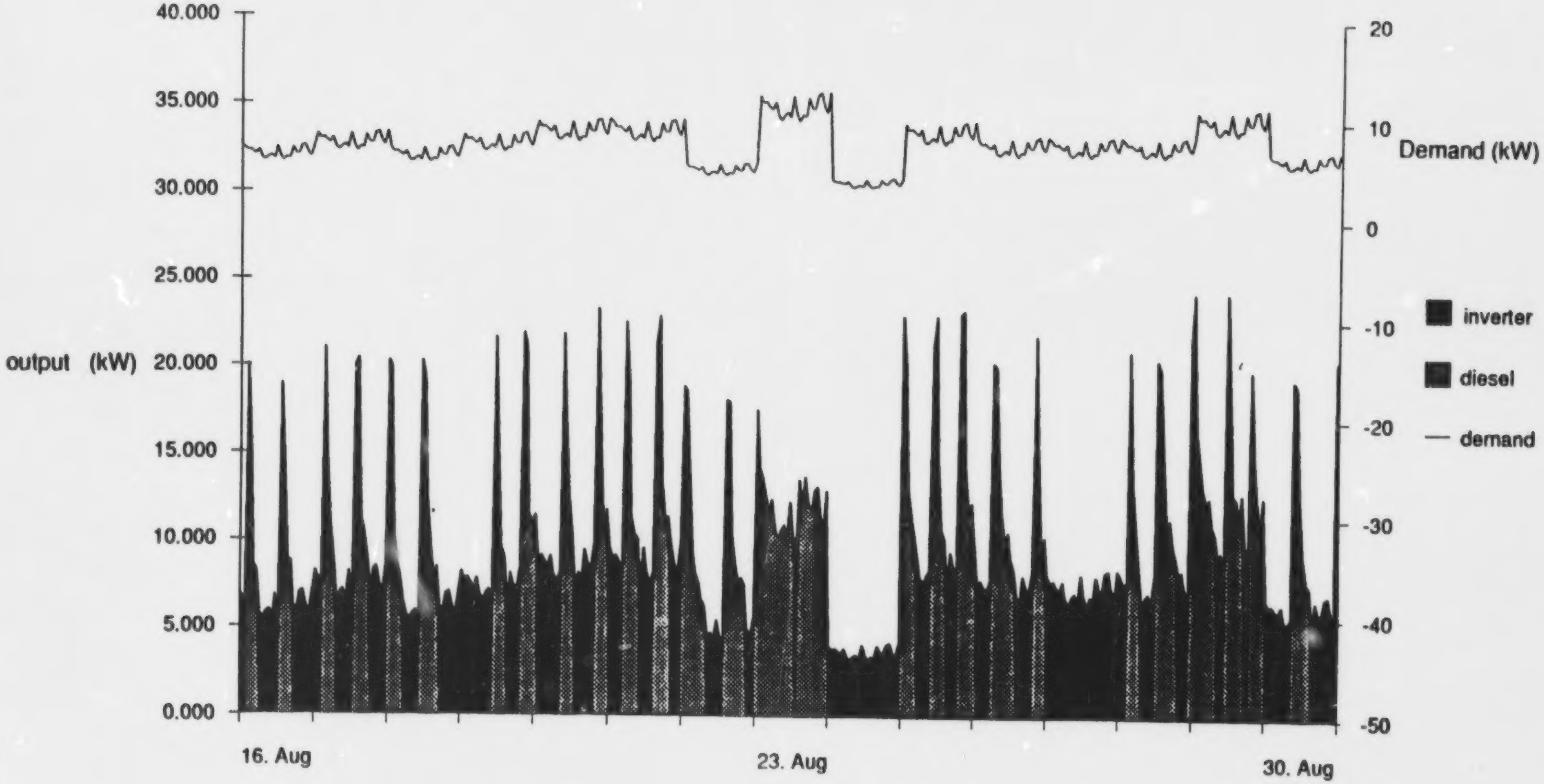
Hindcast Load History (1. Aug - 15. Aug)



August, 1989

based on actual loads

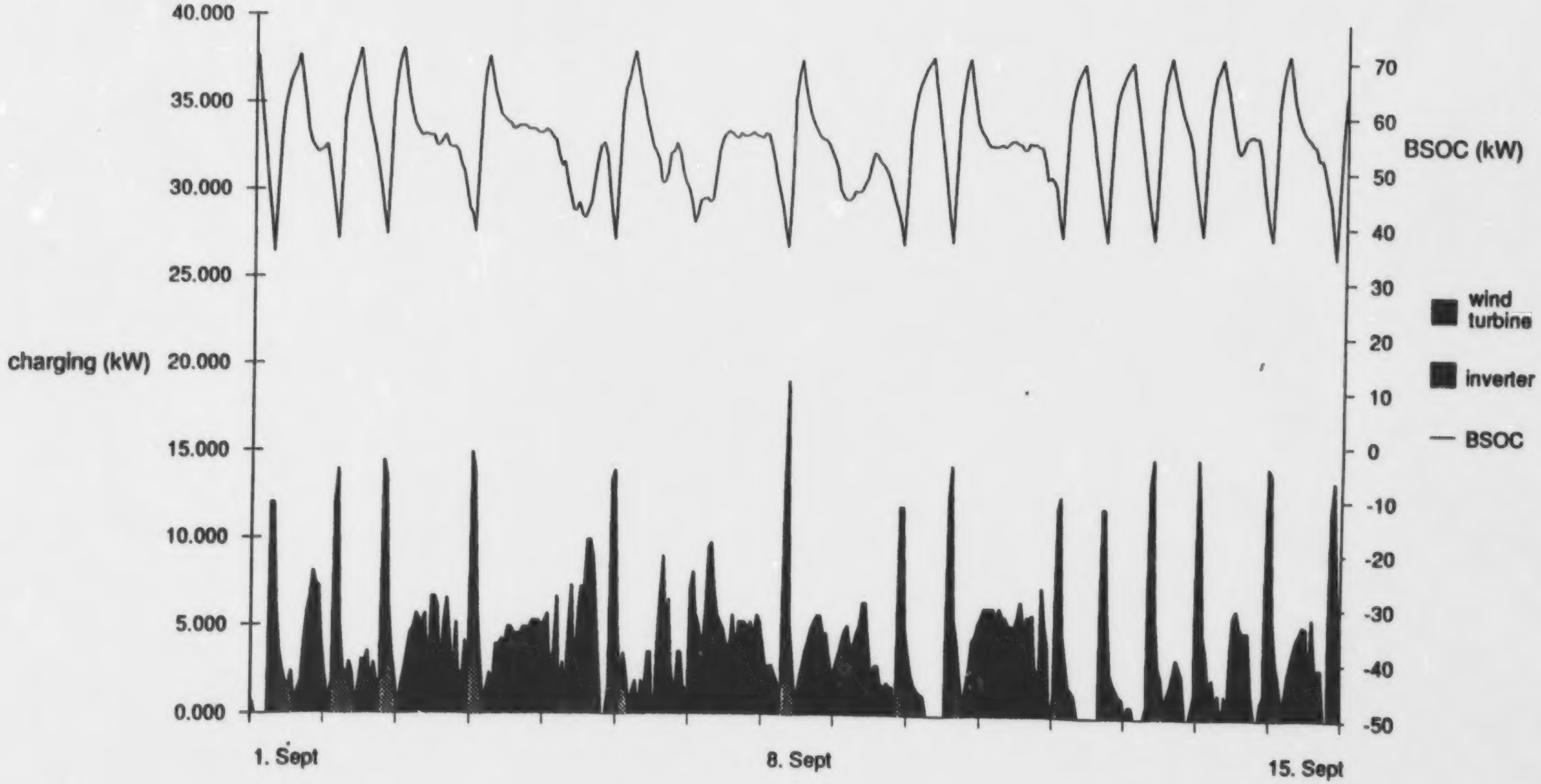
Hindcast Load History (16. Aug - 30. Aug)



August, 1989

based on 60% of actual loads

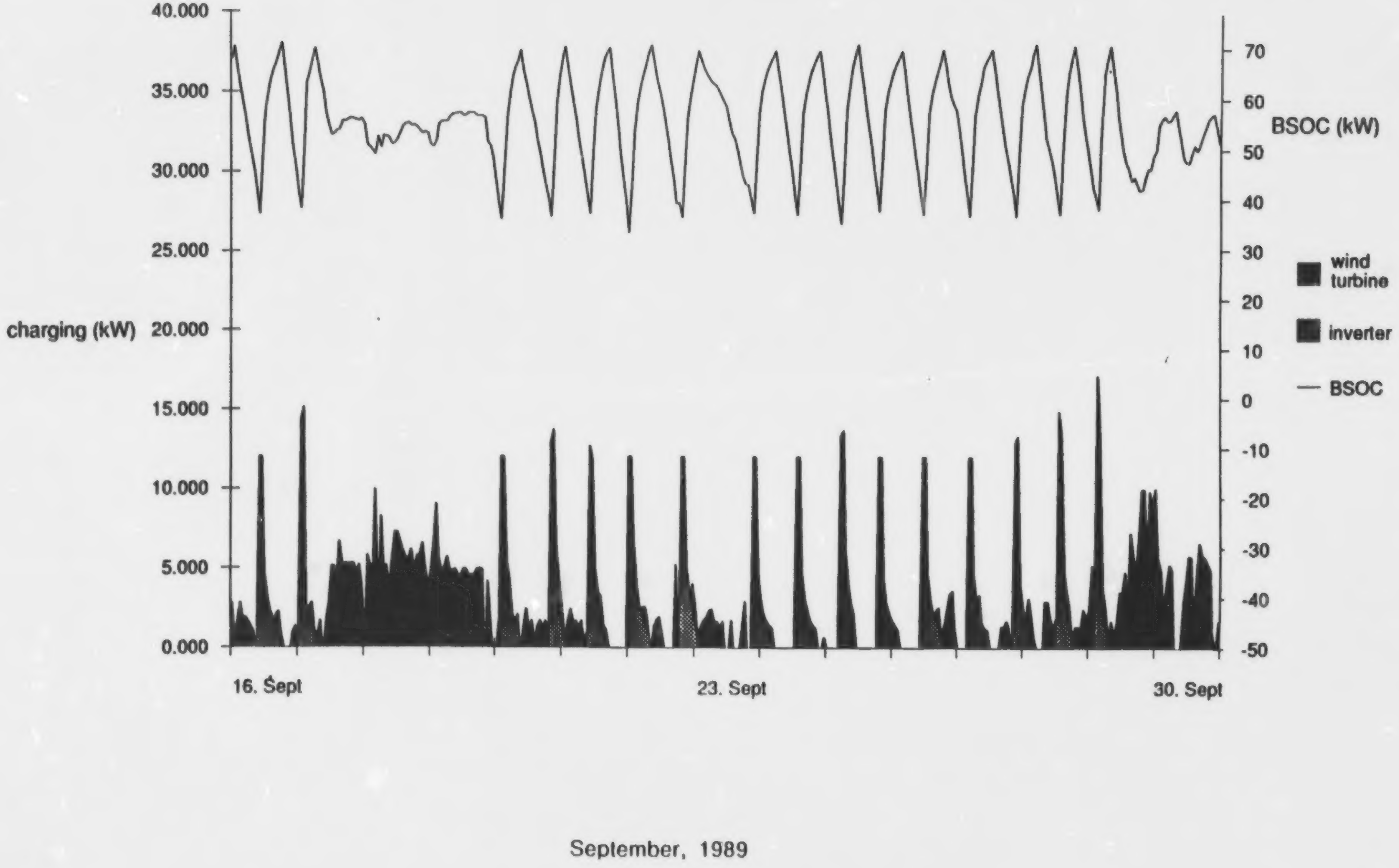
Hindcast Battery Charging History (1. Sept - 15. Sept)



September, 1989

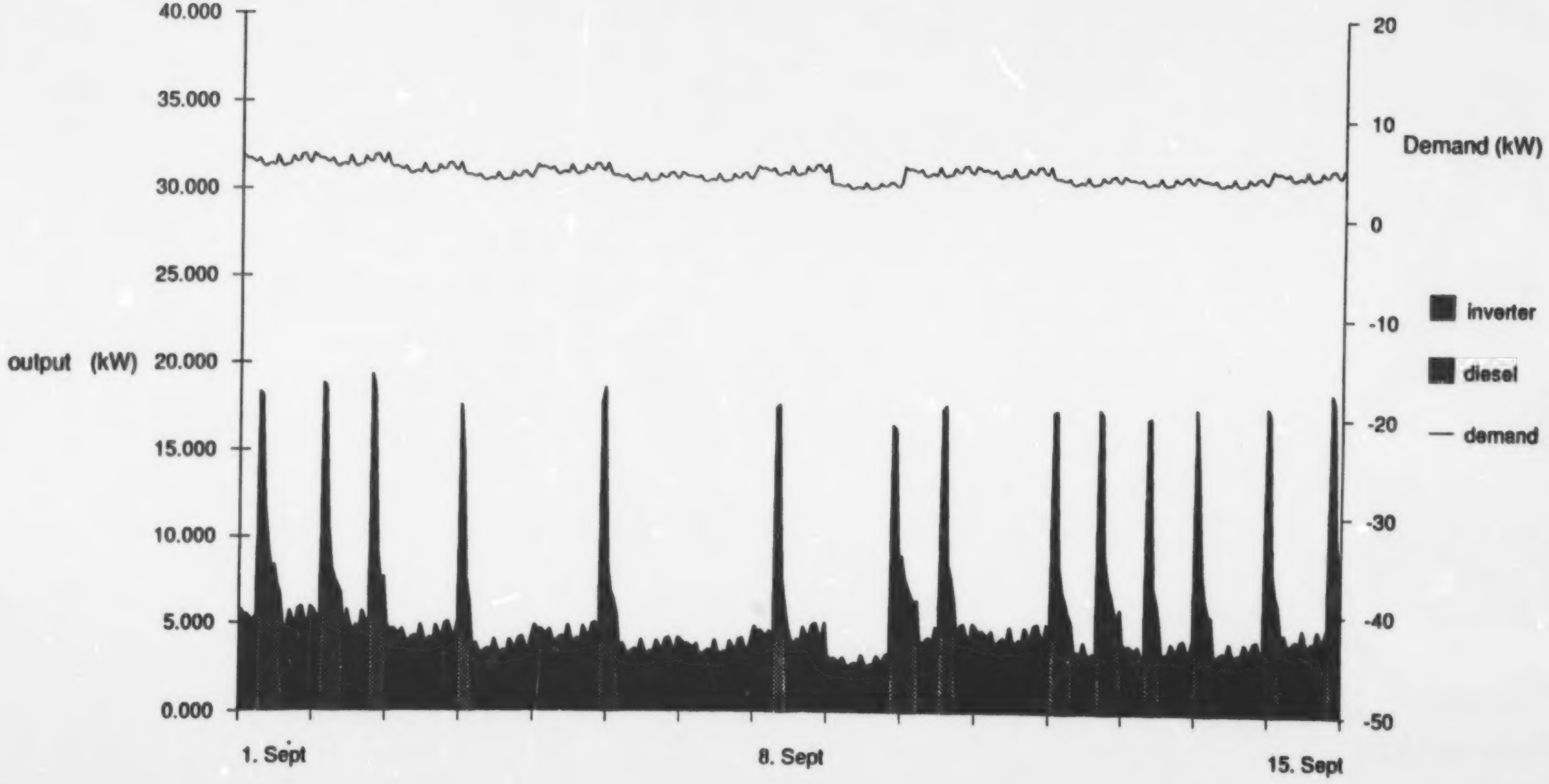
based on 60% of actual loads

Hindcast Battery Charging History (16. Sept - 30. Sept)



based on 60% of actual loads

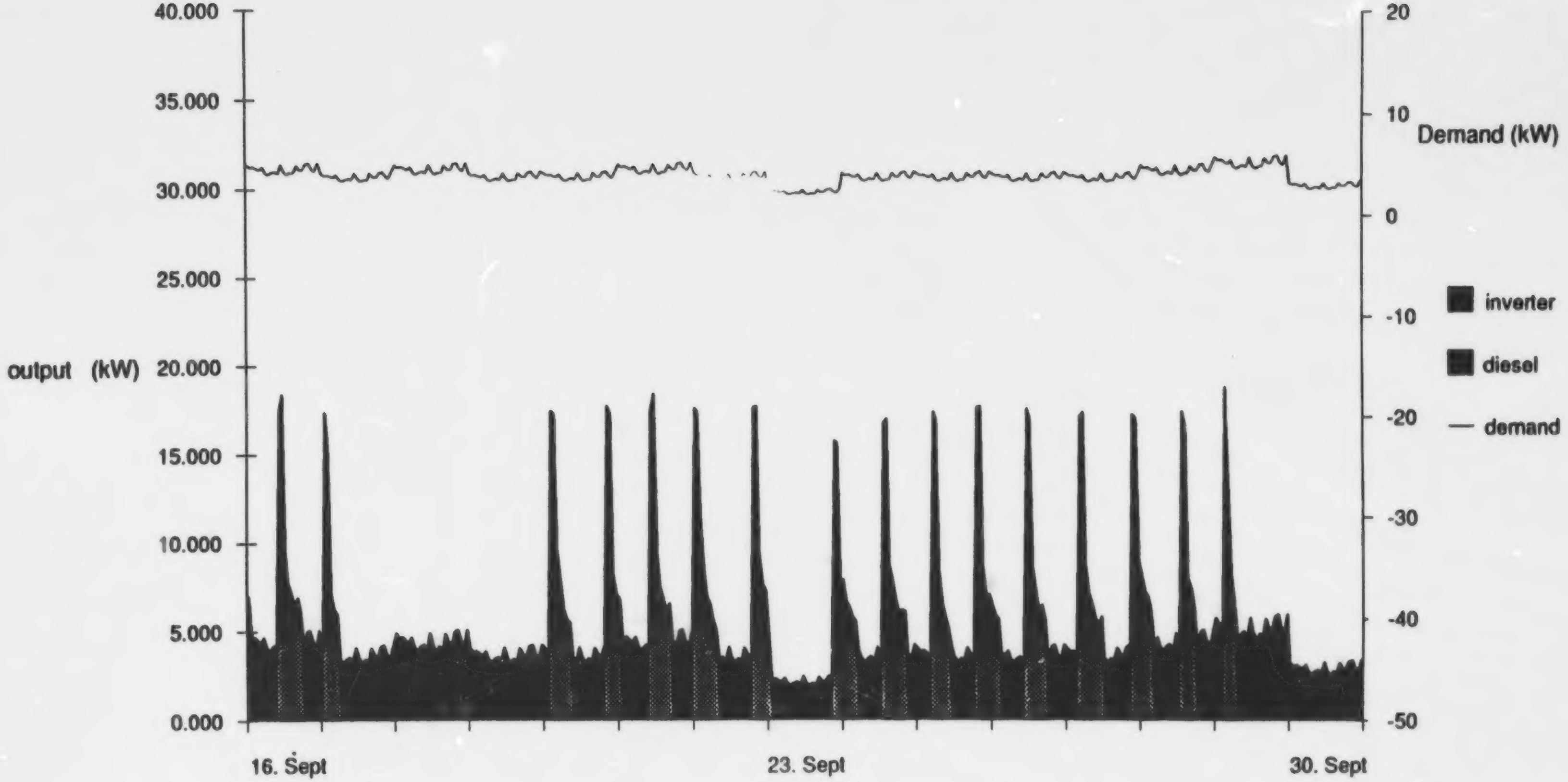
Hindcast Load History (1. Sept - 15. Sept)



September, 1989

based on 60% of actual loads

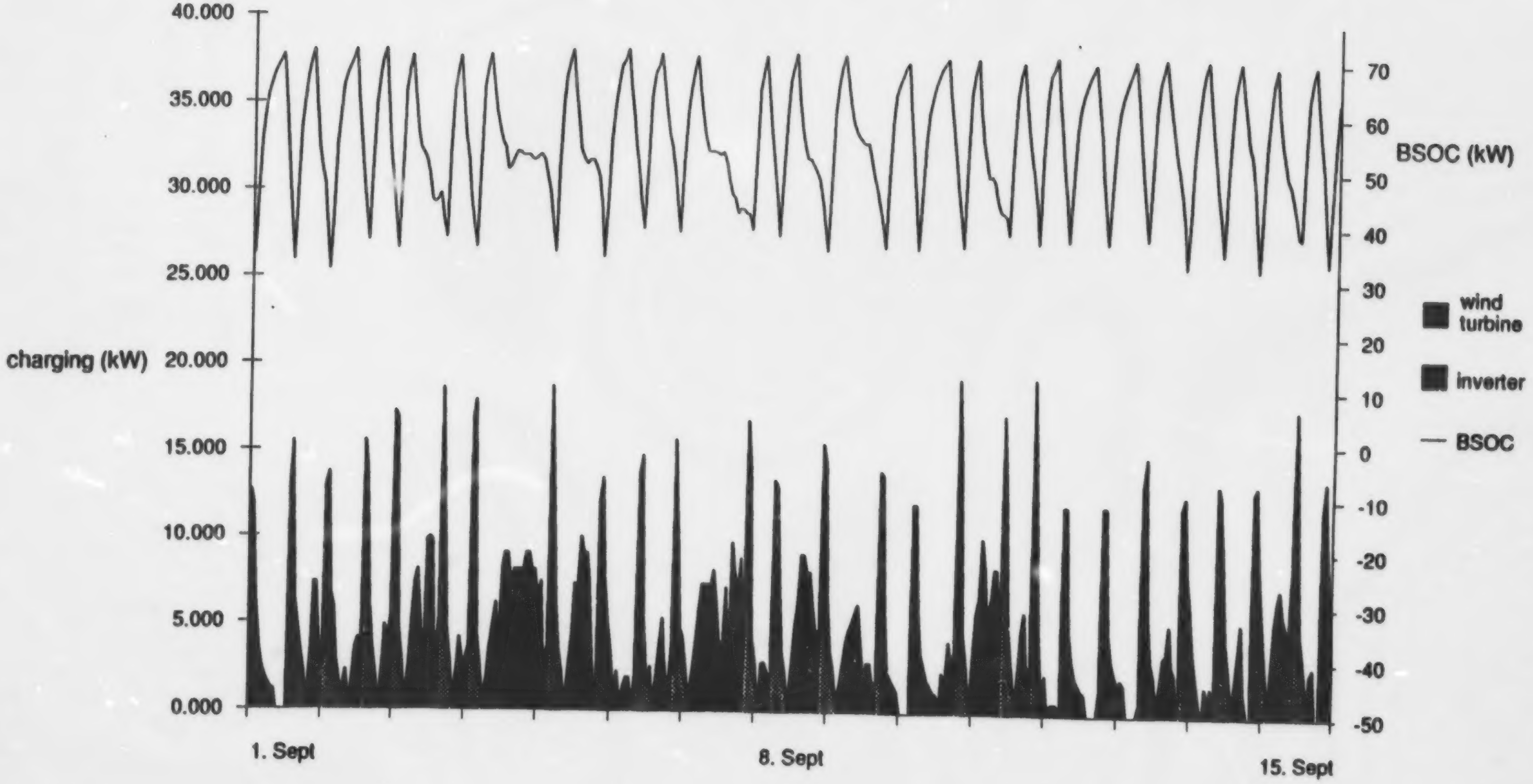
Hindcast Load History (16. Sept - 30. Sept)



September, 1989

based on actual loads

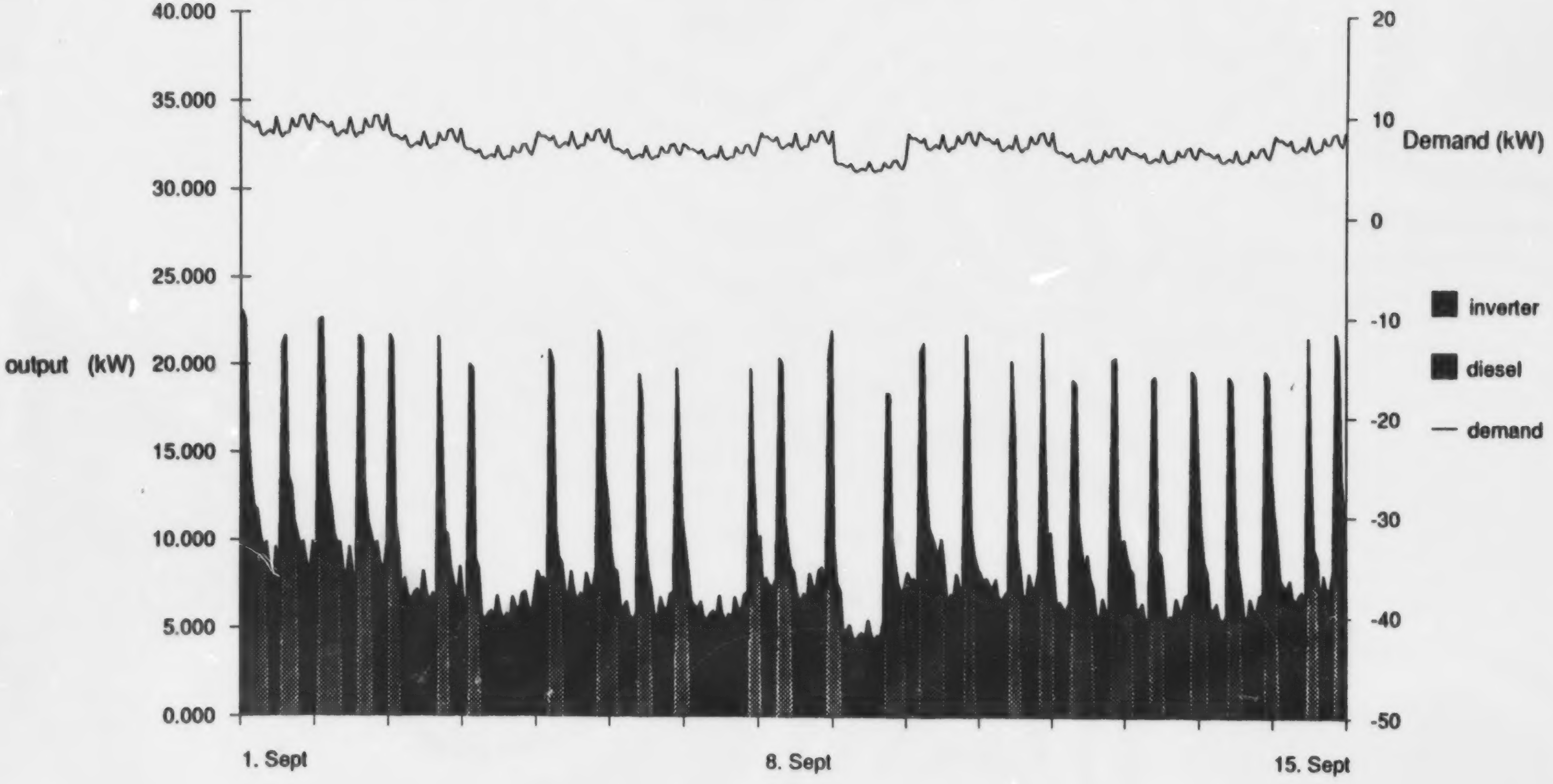
Hindcast Battery Charging History (1. Sept - 15. Sept)



September, 1989

based on actual loads

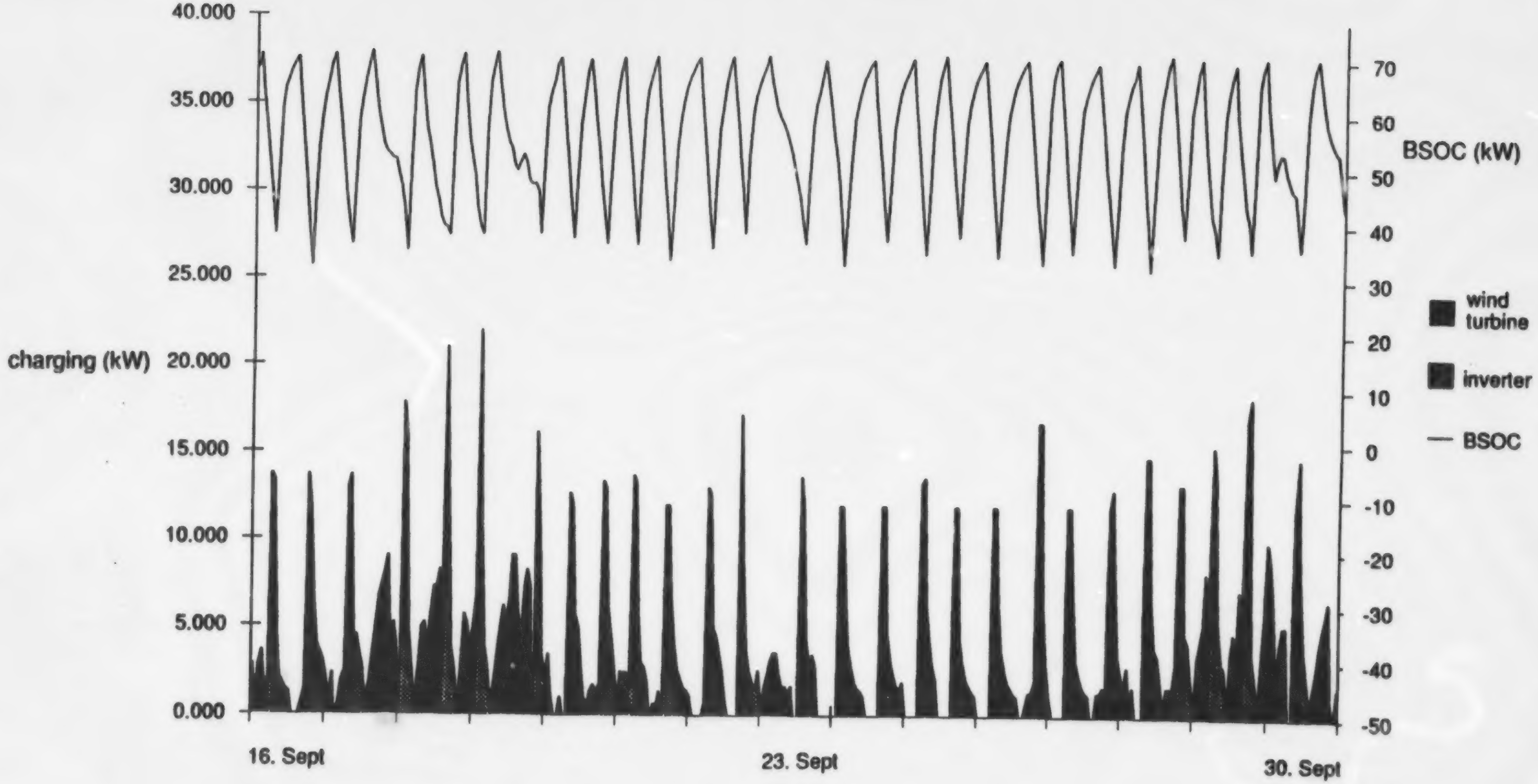
Hindcast Load History (1. Sept - 15. Sept)



September, 1989

based on actual loads

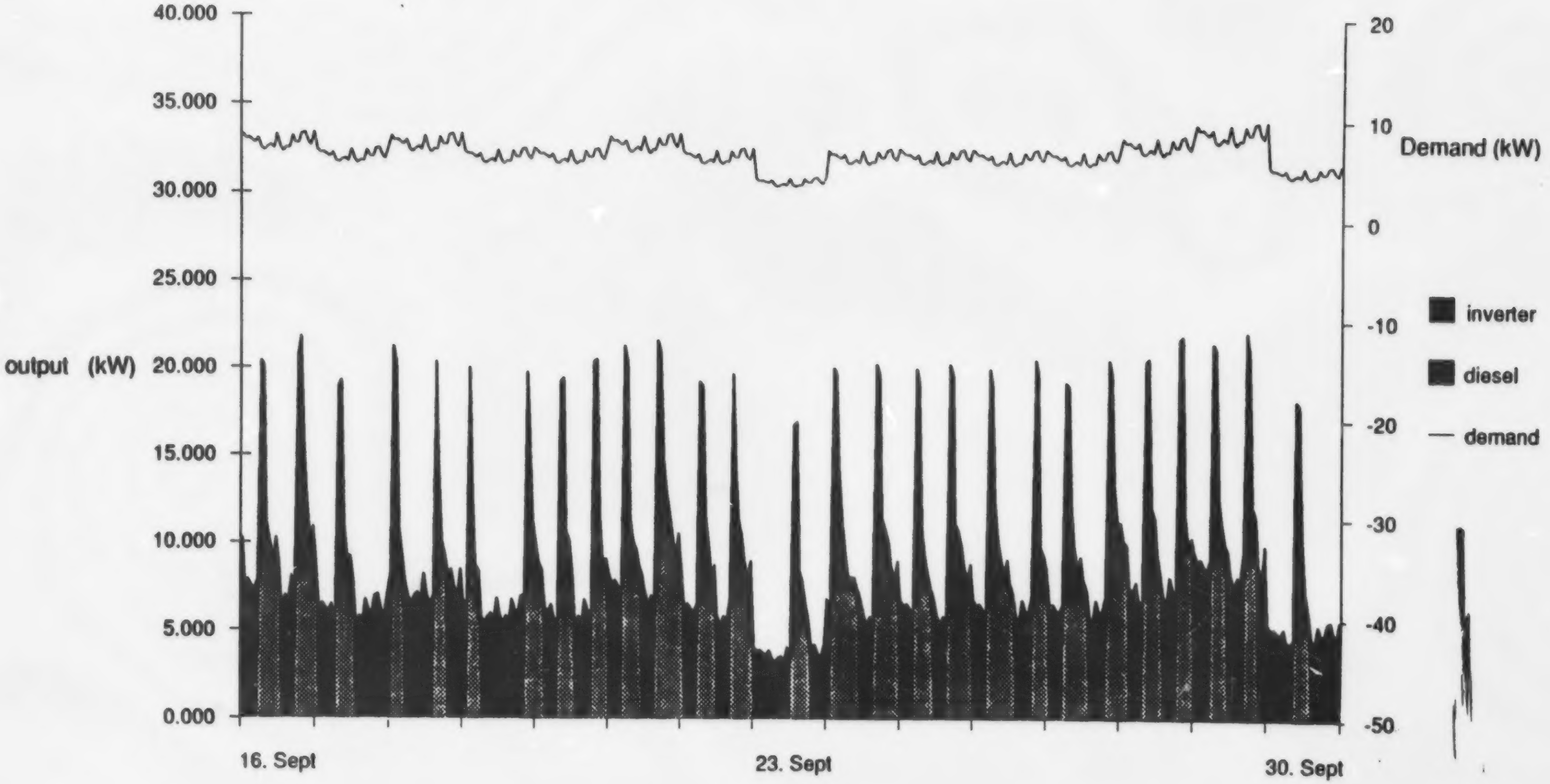
Hindcast Battery Charging History (16. Sept - 30. Sept)



September, 1989

based on actual loads

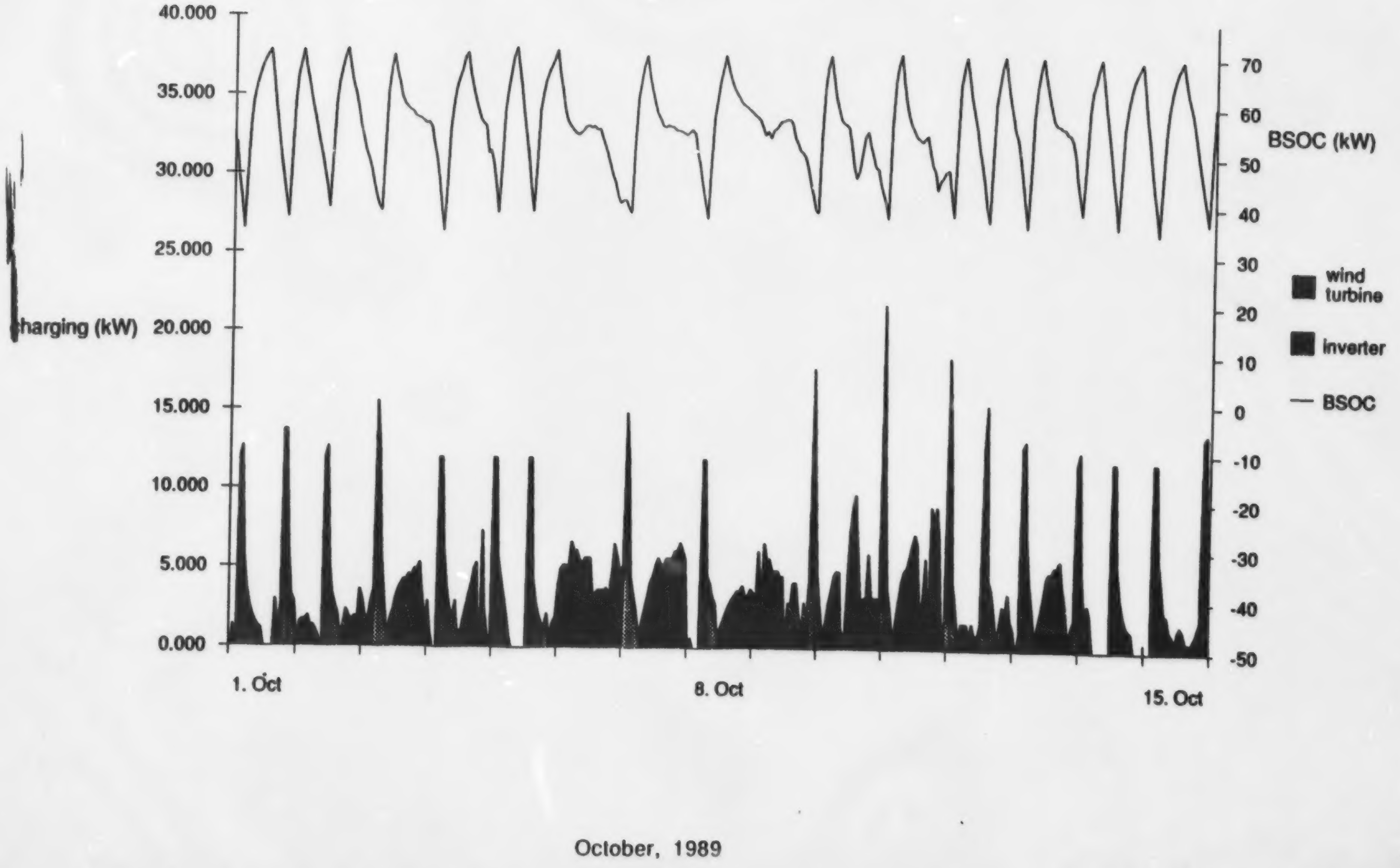
Hindcast Load History (16. Sept - 30. Sept)



September, 1989

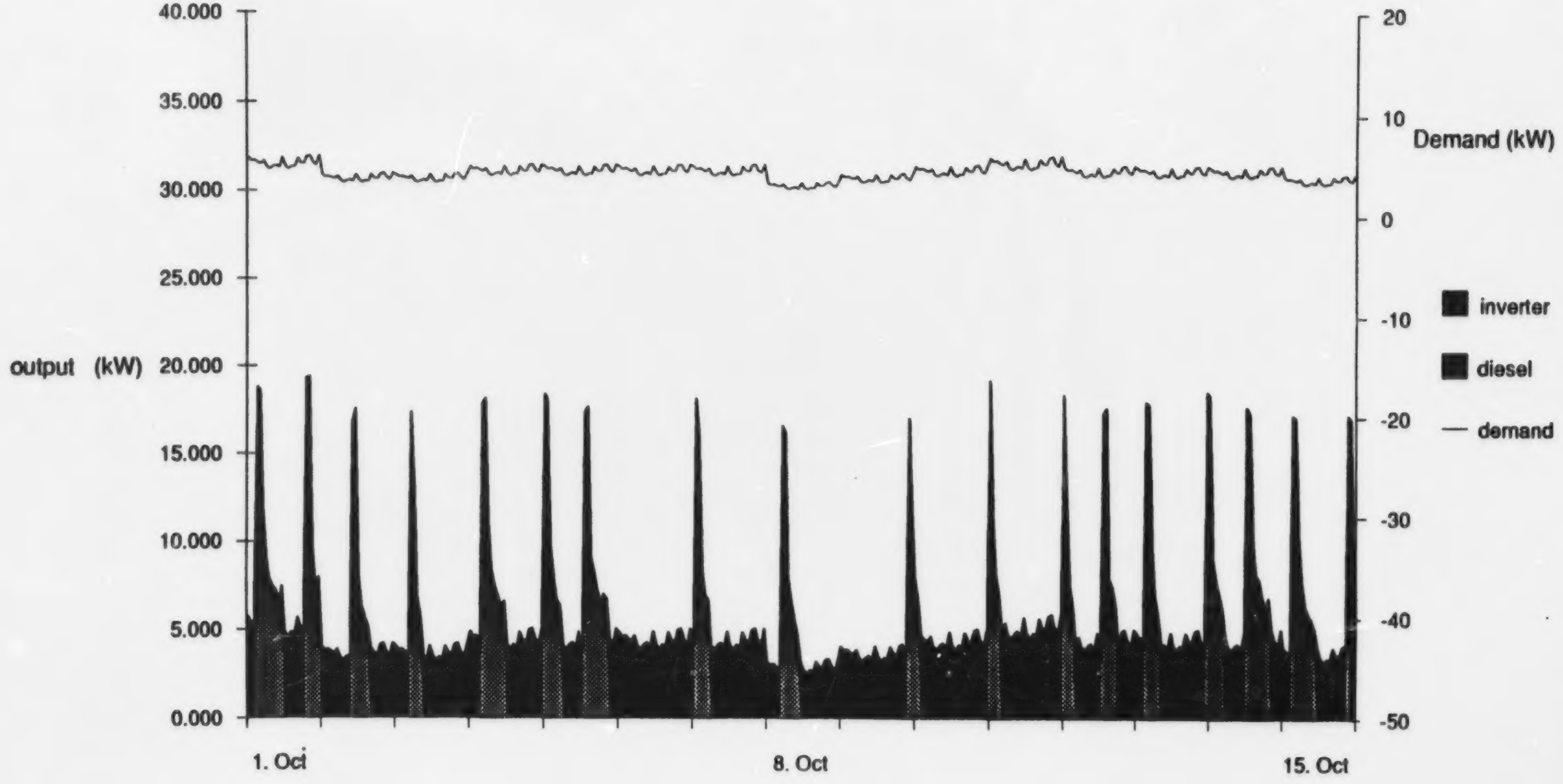
based on 60% of actual loads

Hindcast Battery Charging History (1. Oct - 15. Oct)



based on 60% of actual loads

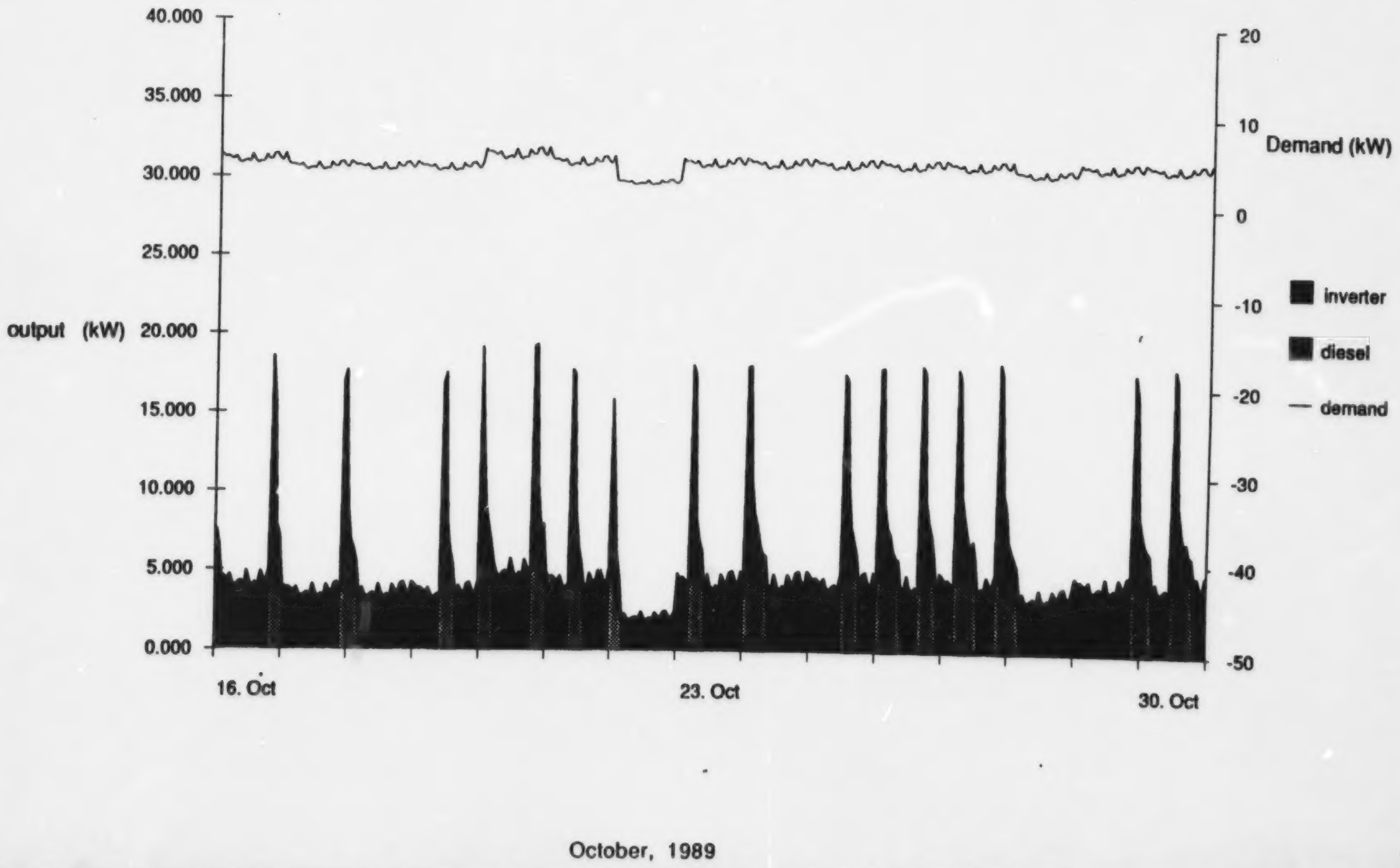
Hindcast Load History (1. Oct - 15. Oct)



October, 1989

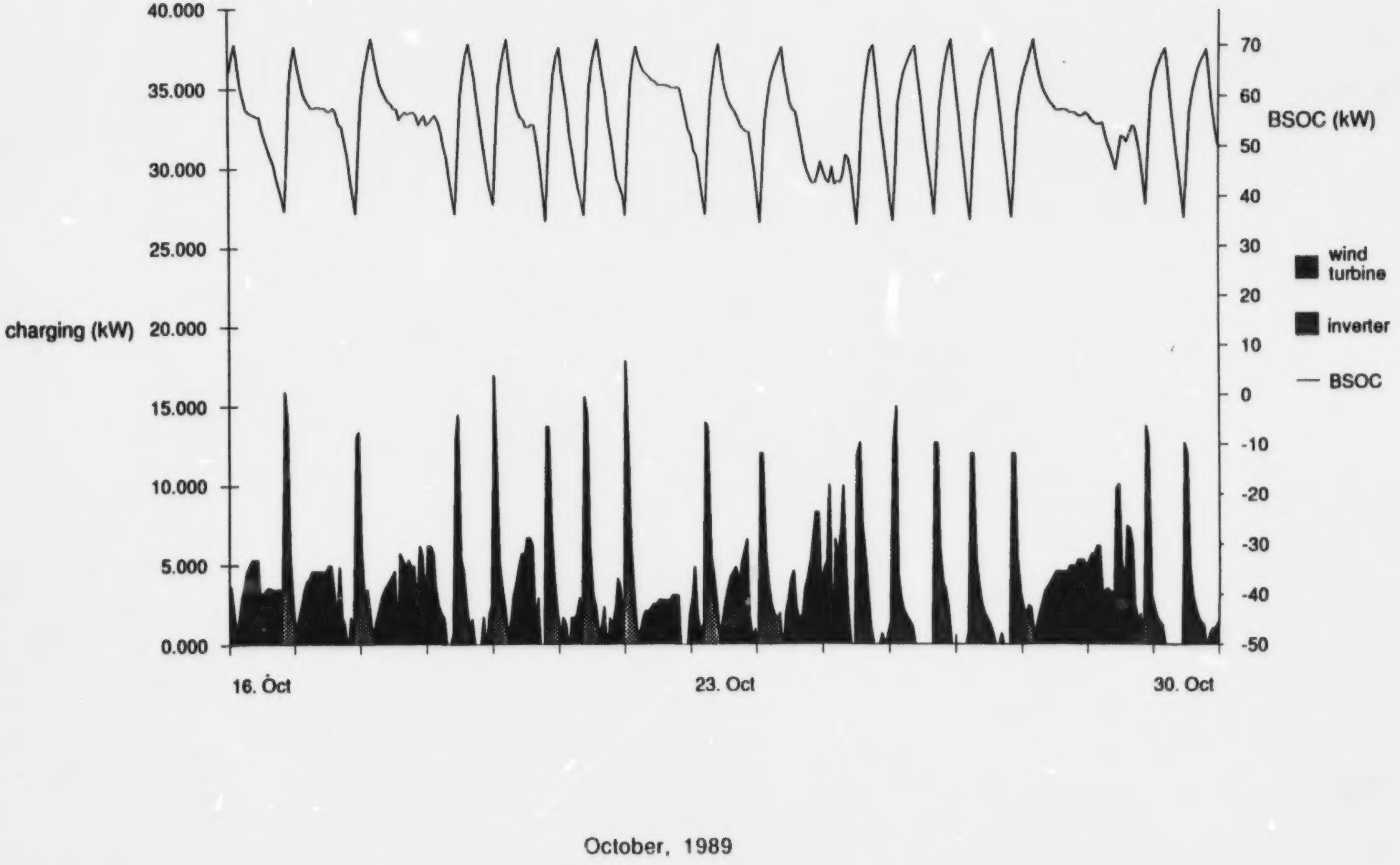
based on 60% of actual loads

Hindcast Load History (16. Oct - 30. Oct)



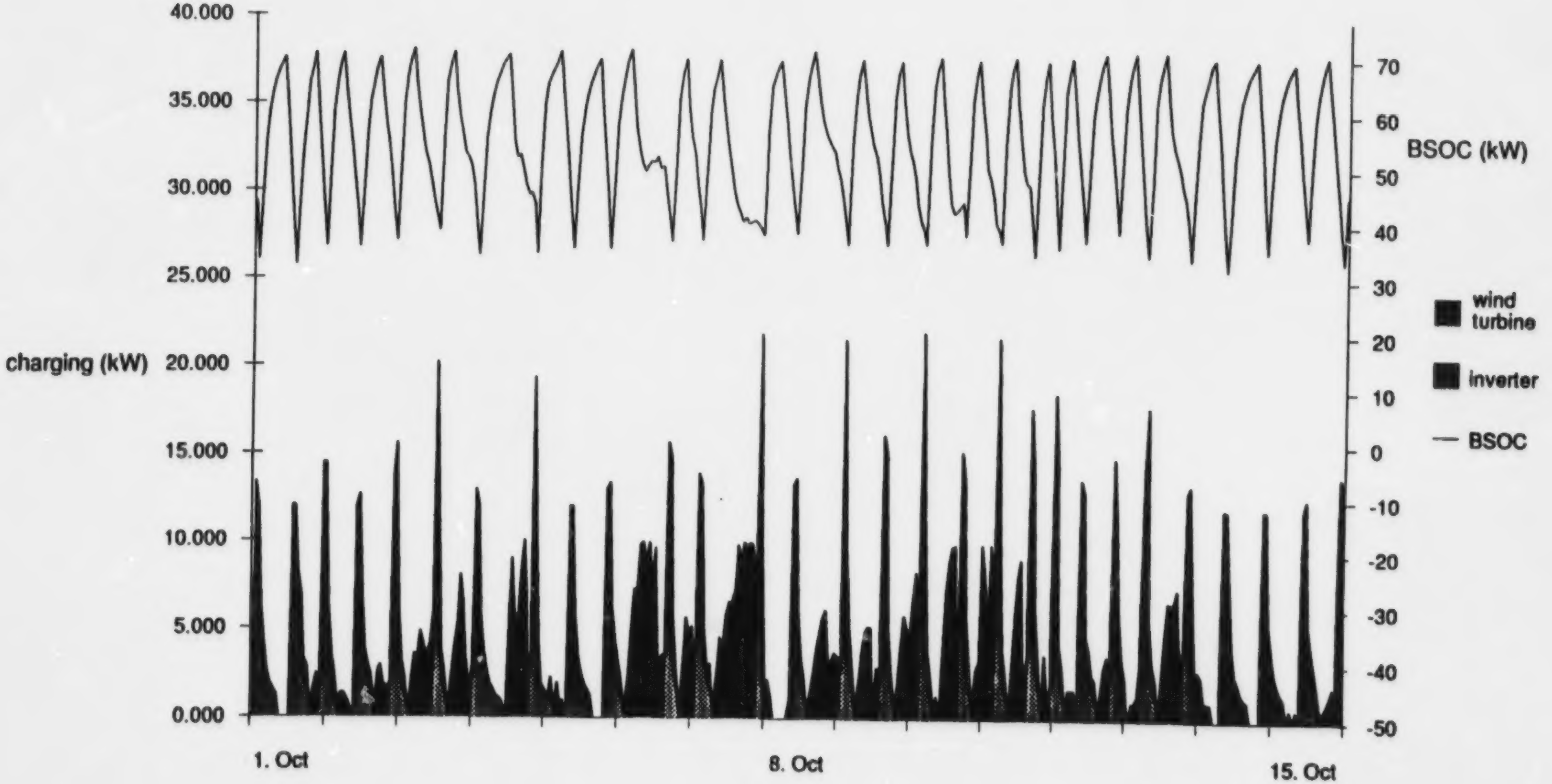
based on 60% of actual loads

Hindcast Battery Charging History (16. Oct - 30. Oct)



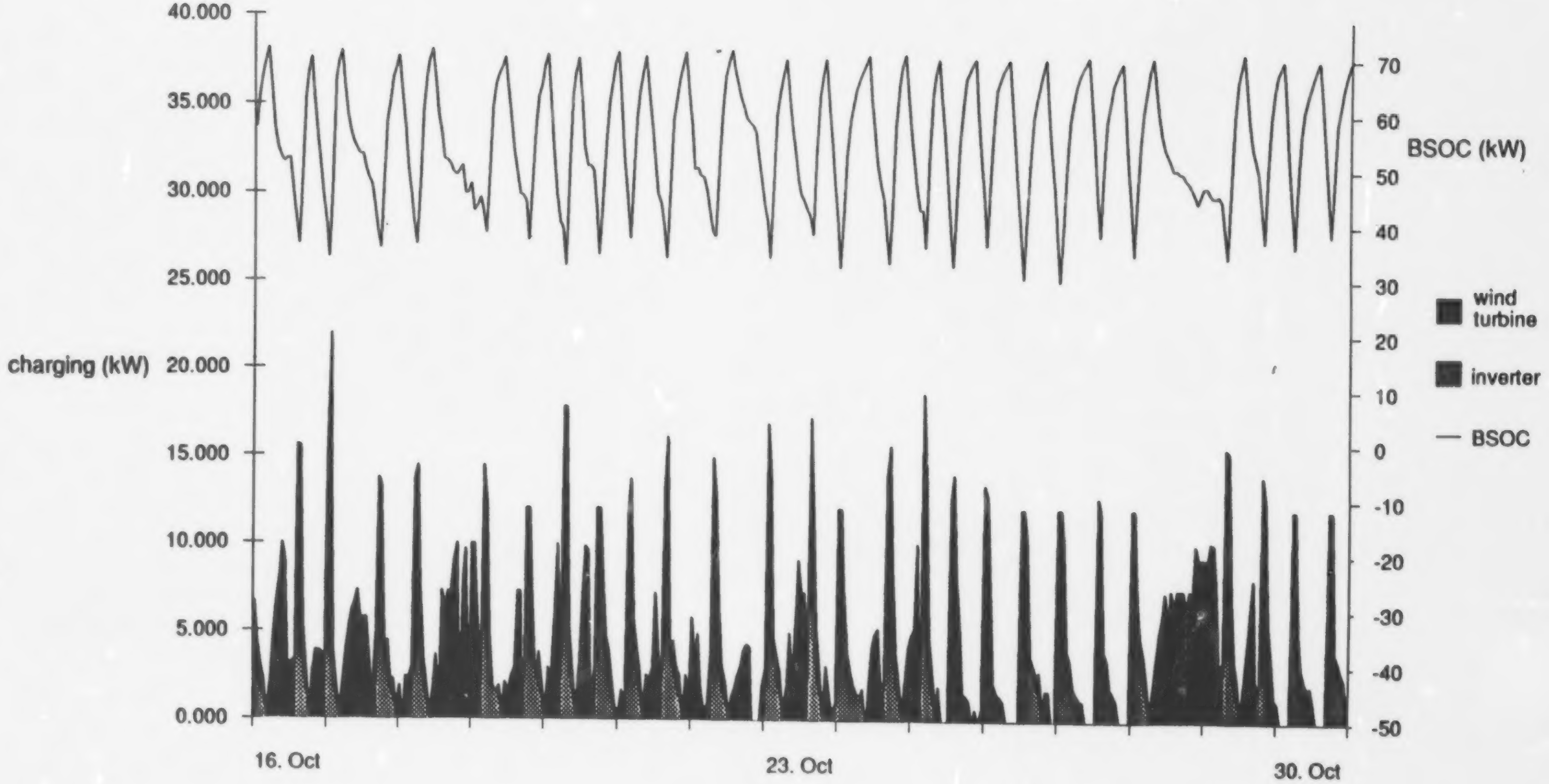
based on actual loads

Hindcast Battery Charging History (1. Oct - 15. Oct)



October, 1989

based on actual data

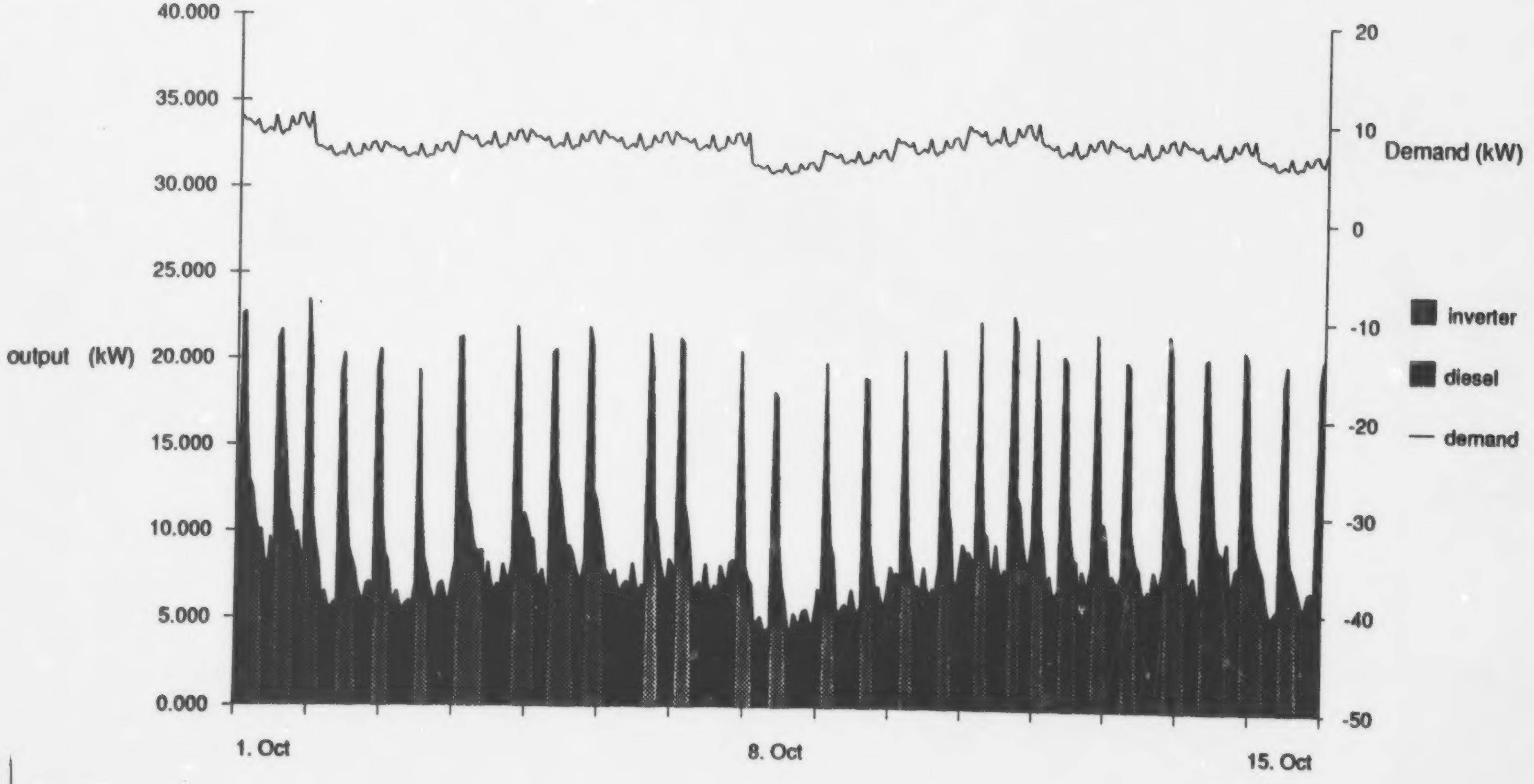


Hindcast Battery Charging History (16. Oct - 30. Oct)

October, 1989

based on actual loads

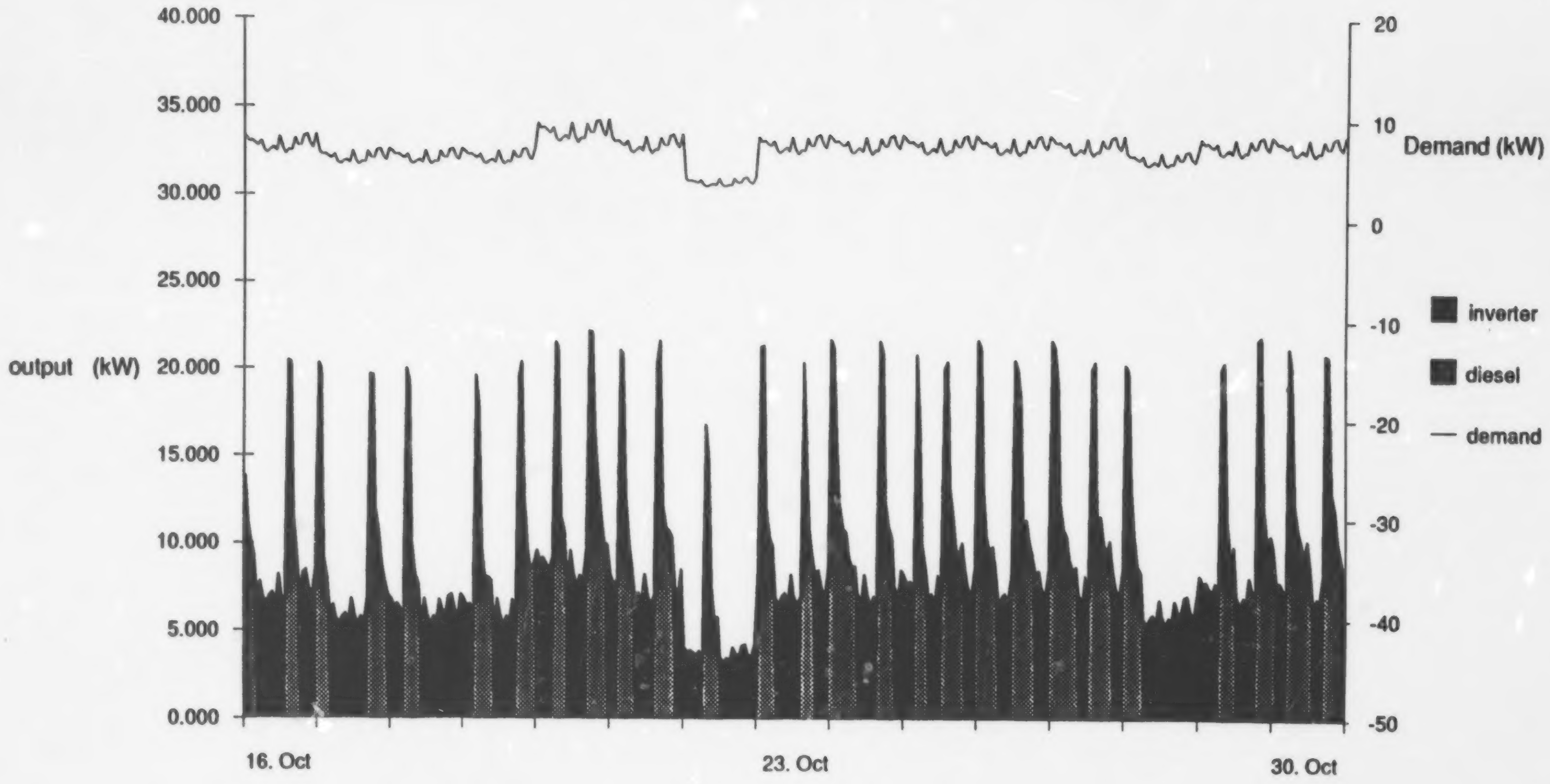
Hindcast Load History (1. Oct - 15. Oct)



October, 1989

based on actual loads

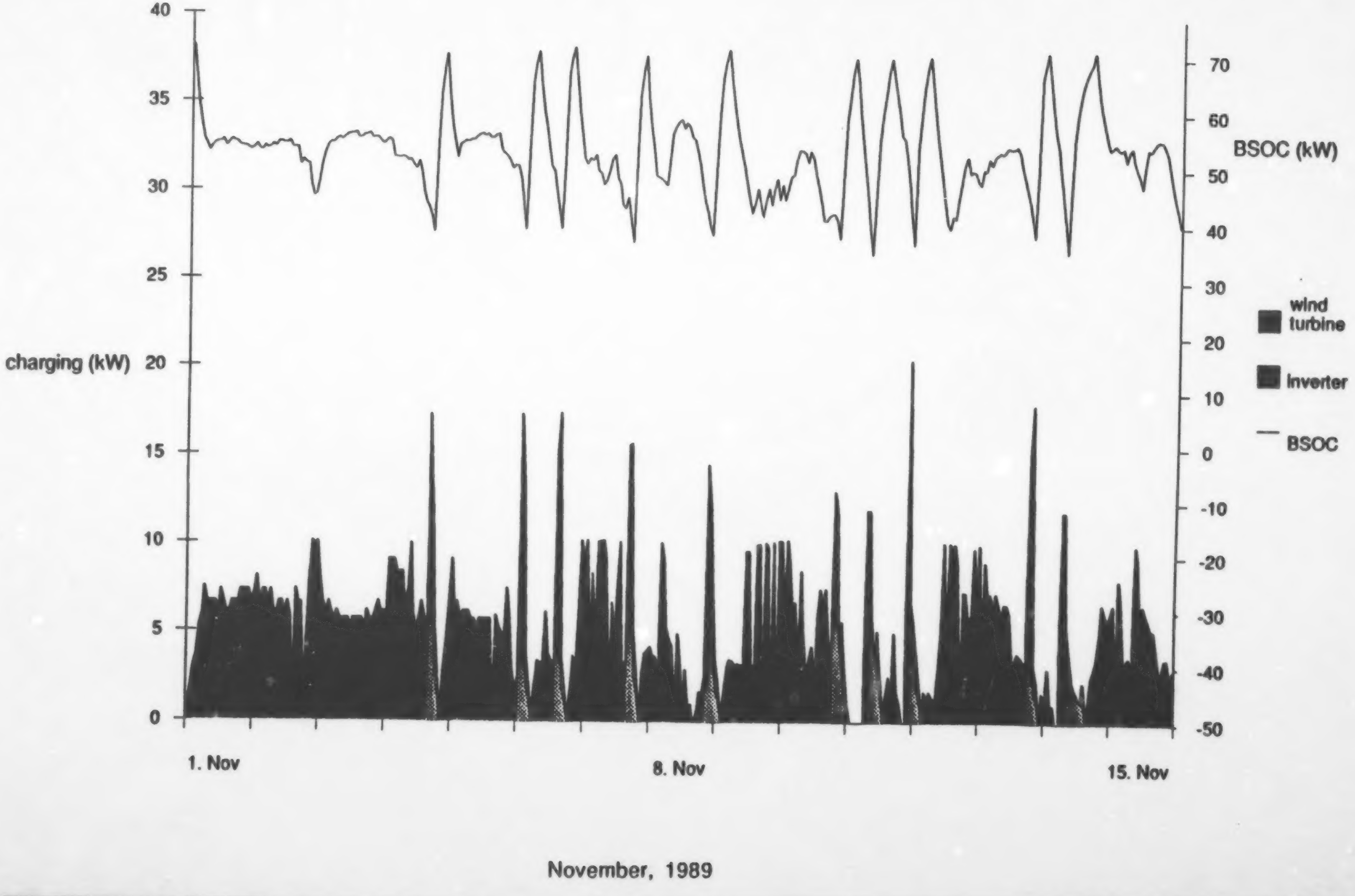
Hindcast Load History (16. Oct - 30. Oct)



October, 1989

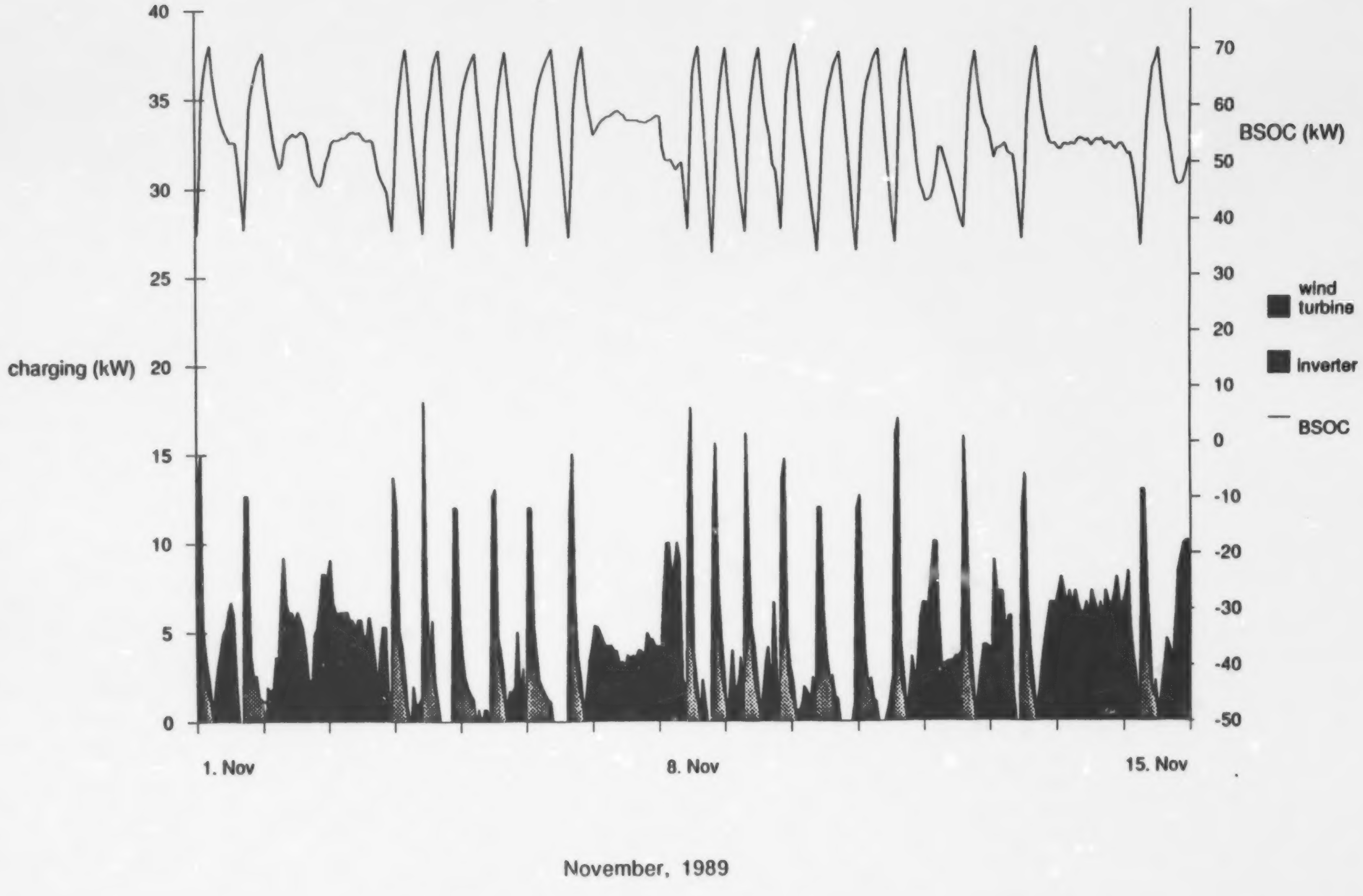
based on 60% of actual loads

Hindcast Battery Charging History (1. Nov - 15. Nov)



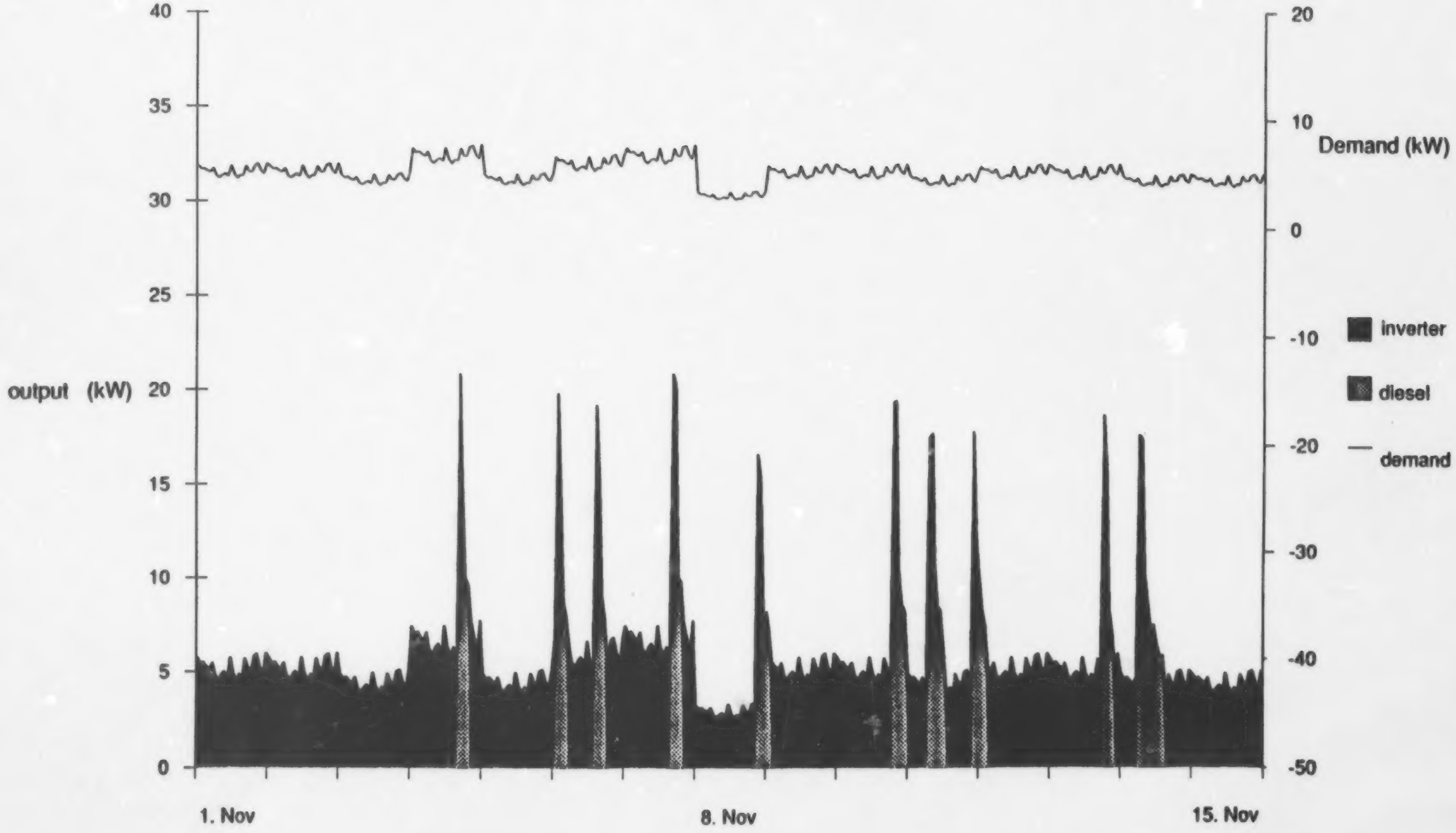
based on 60% of actual loads

Hindcast Battery Charging History (16. Nov - 30. Nov)



based on 60% of actual loads

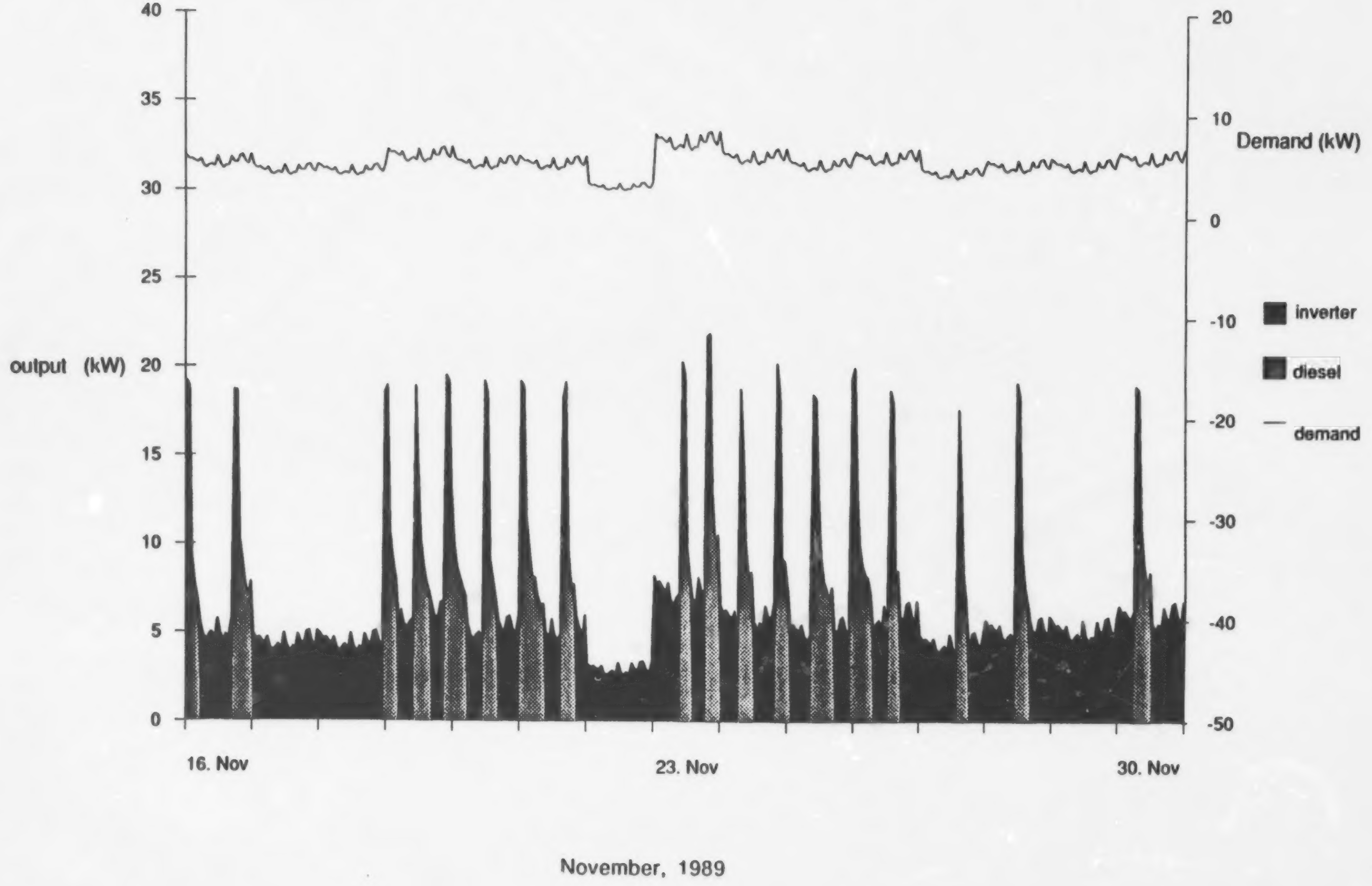
Hindcast Load History (1. Nov - 15. Nov)



November, 1989

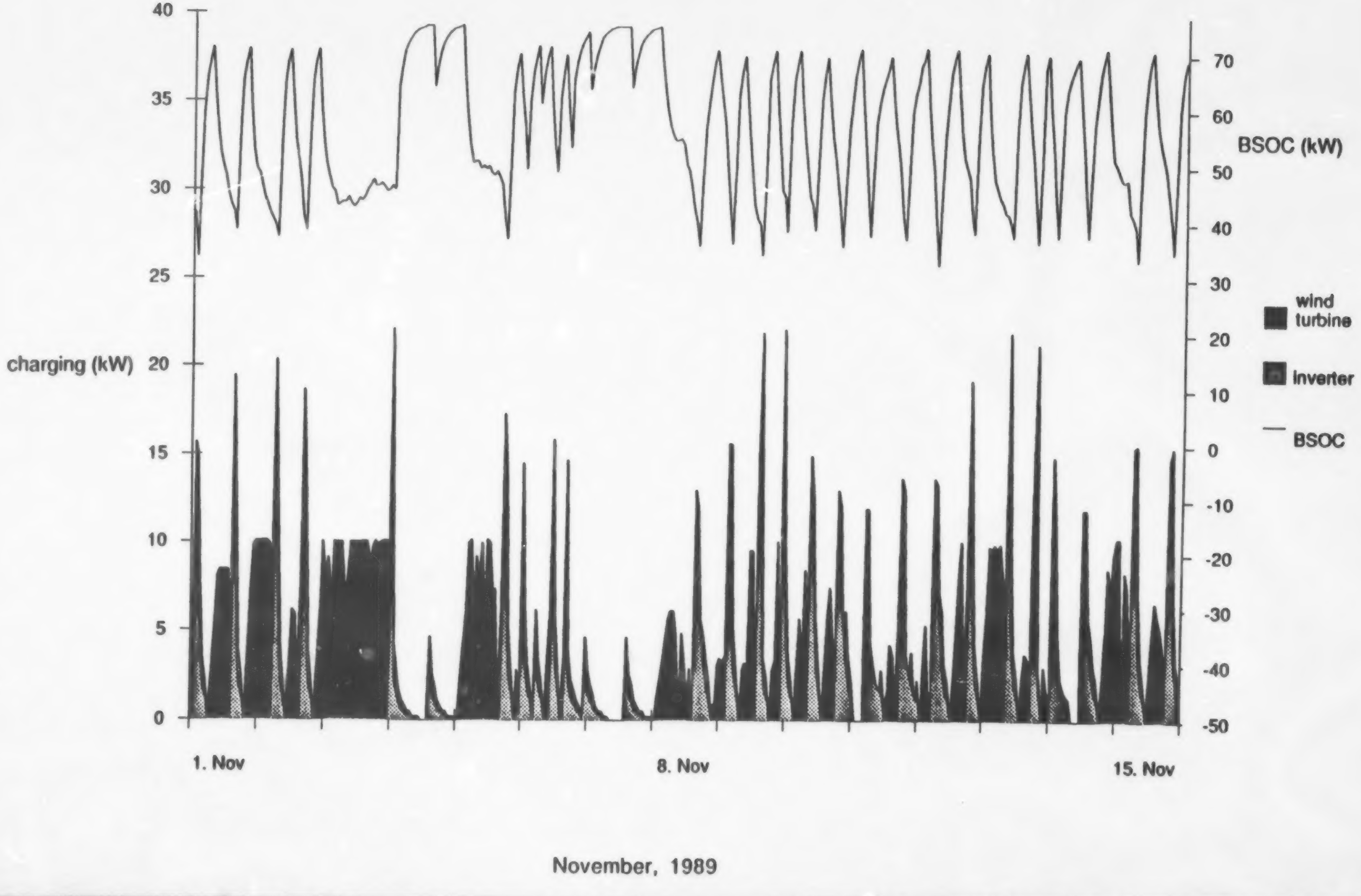
based on 60% of actual loads

Hindcast Load History (16. Nov - 30. Nov)



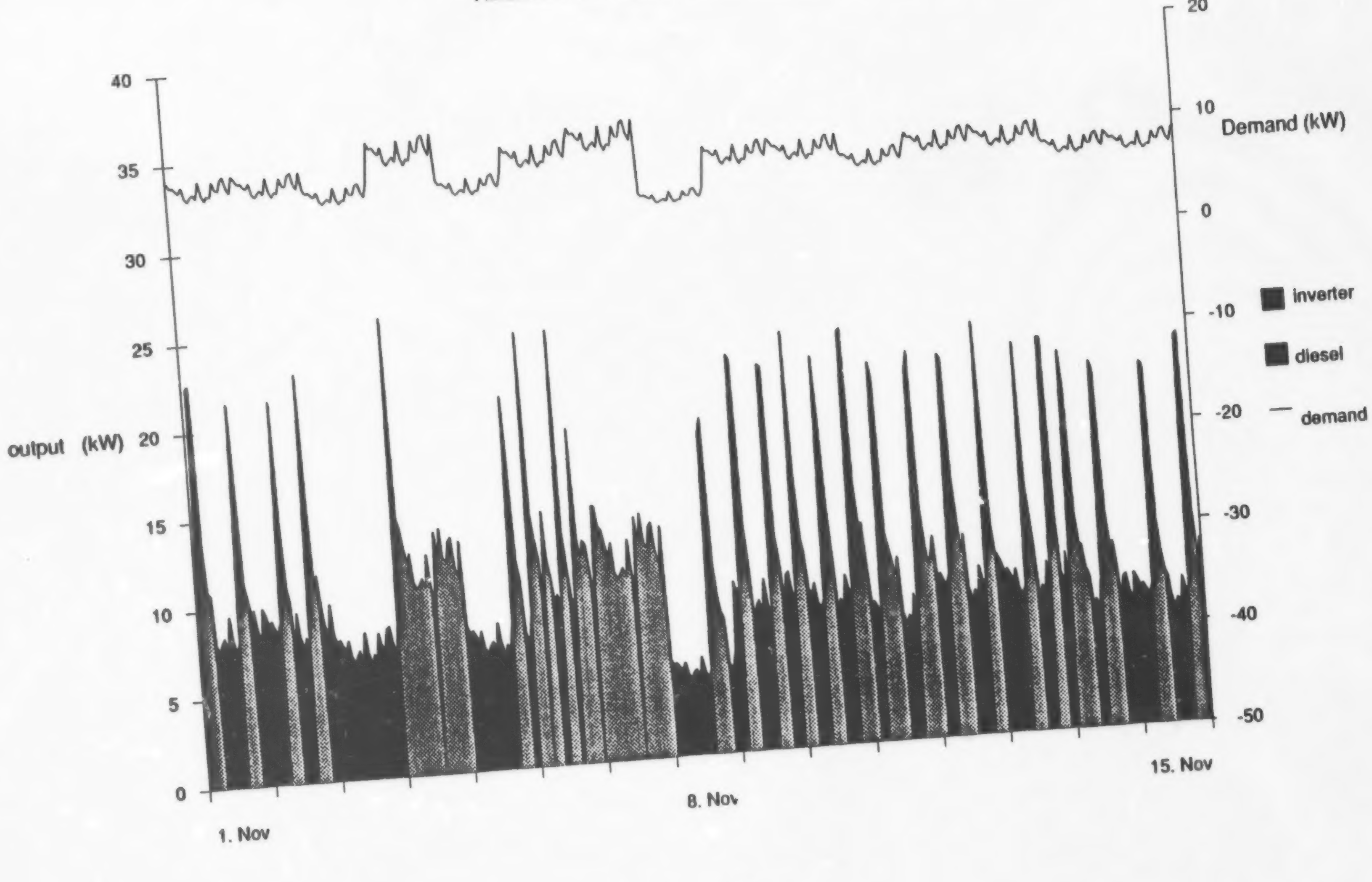
based on actual loads

Hindcast Battery Charging History (1. Nov - 15. Nov)



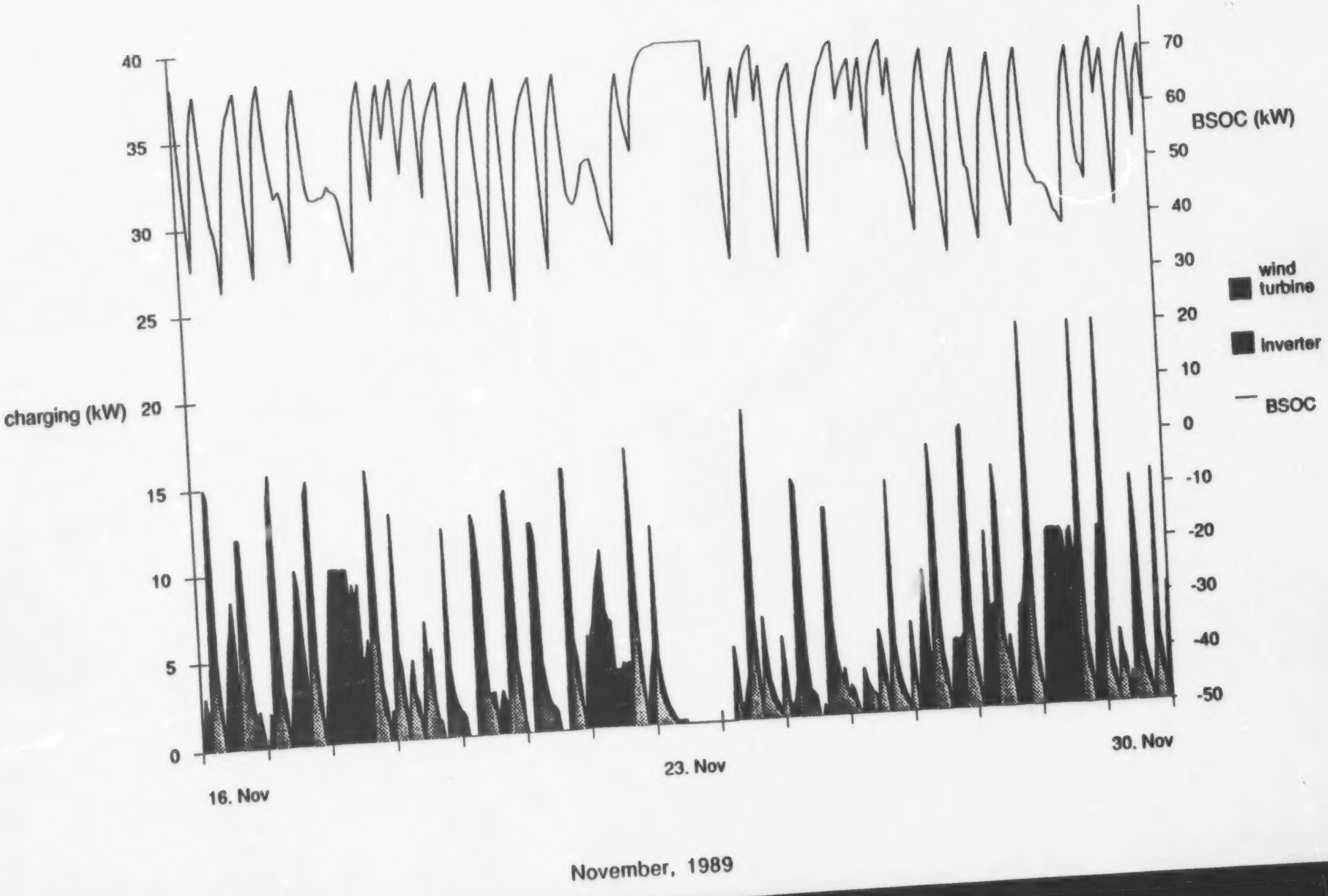
based on actual loads

Hindcast Load History (1. Nov - 15. Nov)



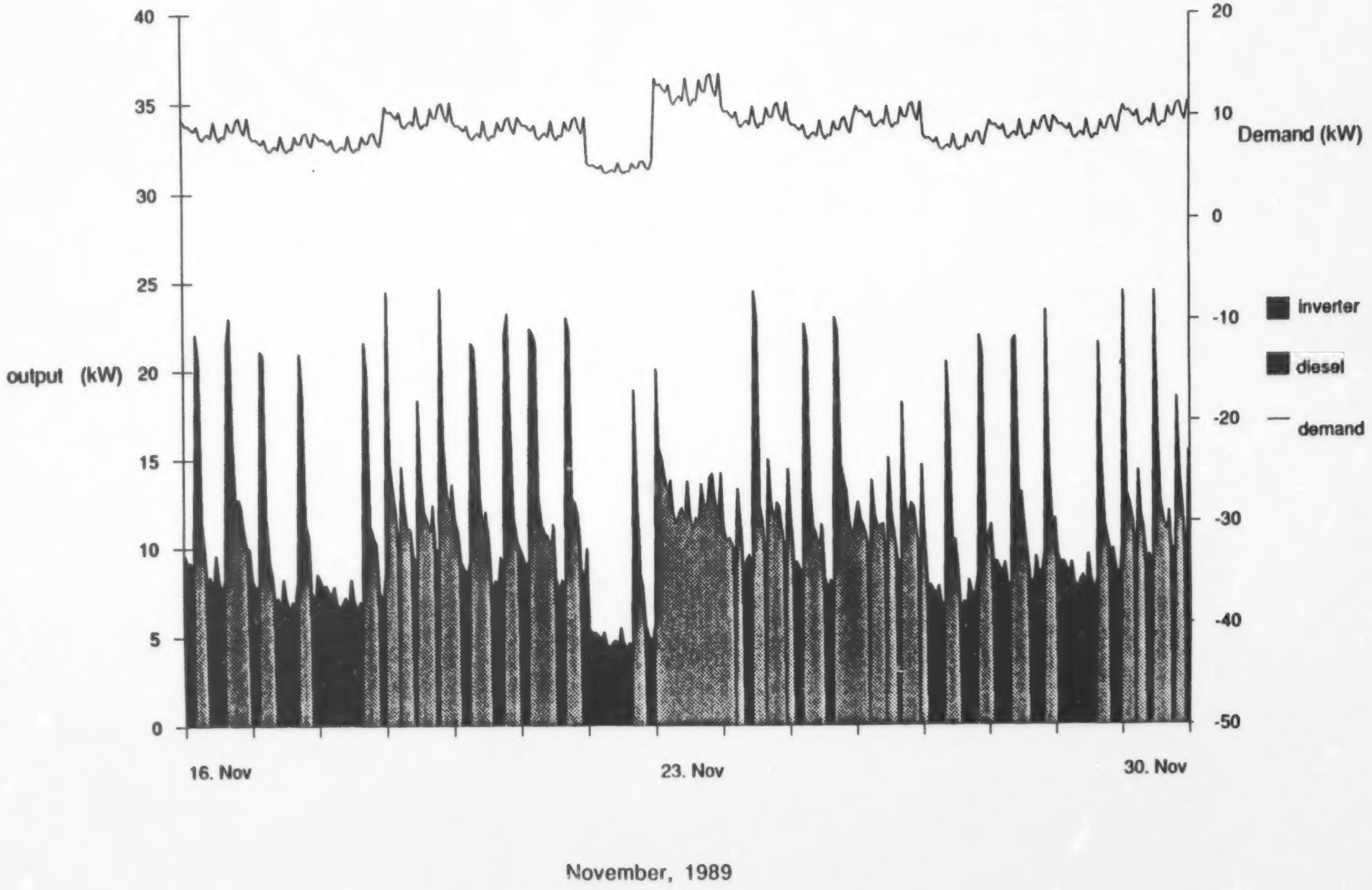
based on actual loads

Hindcast Battery Charging History (16. Nov - 30. Nov)



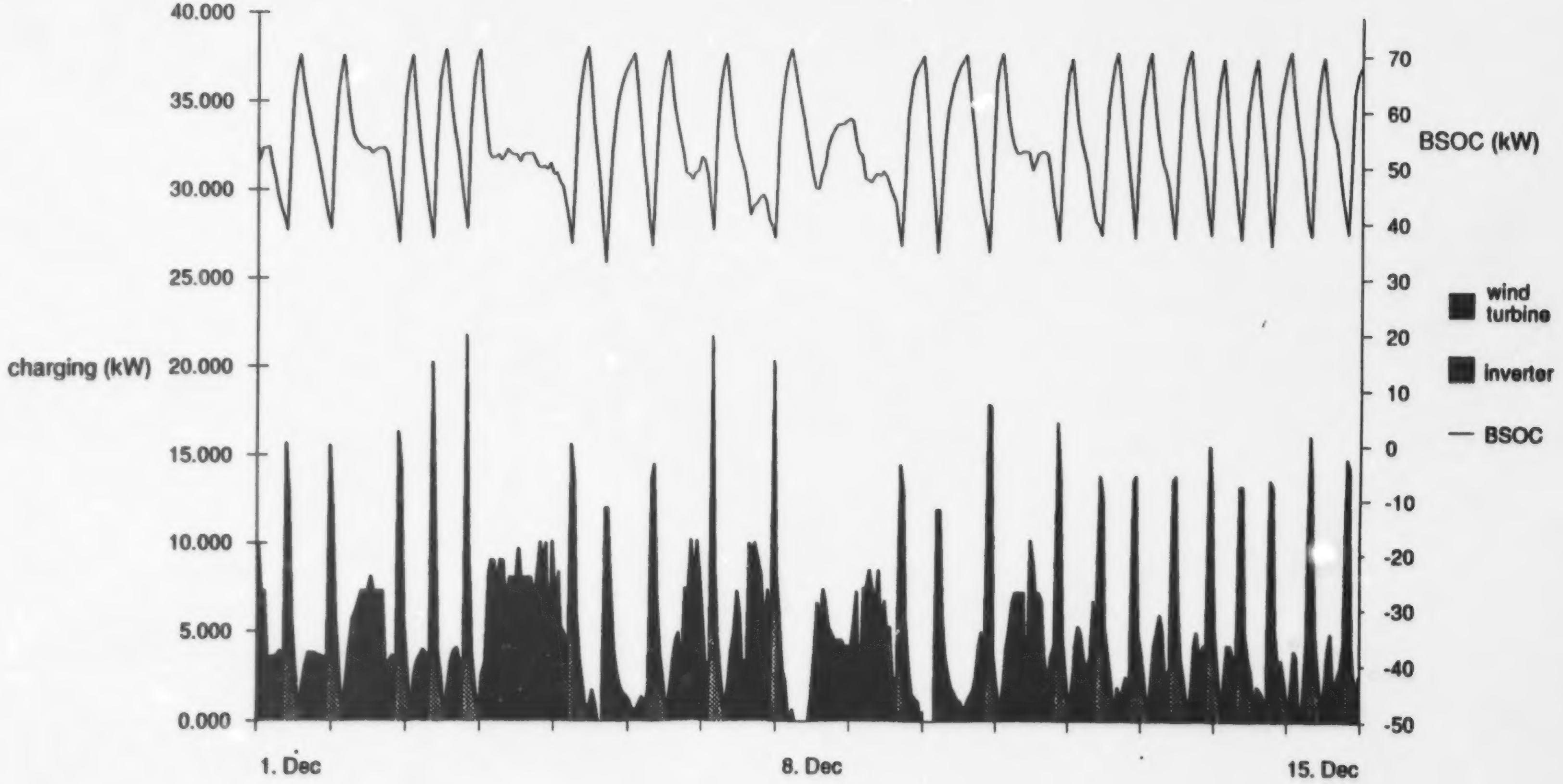
based on actual loads

Hindcast Load History (16. Nov - 23. Nov)



based on 60% of actual loads

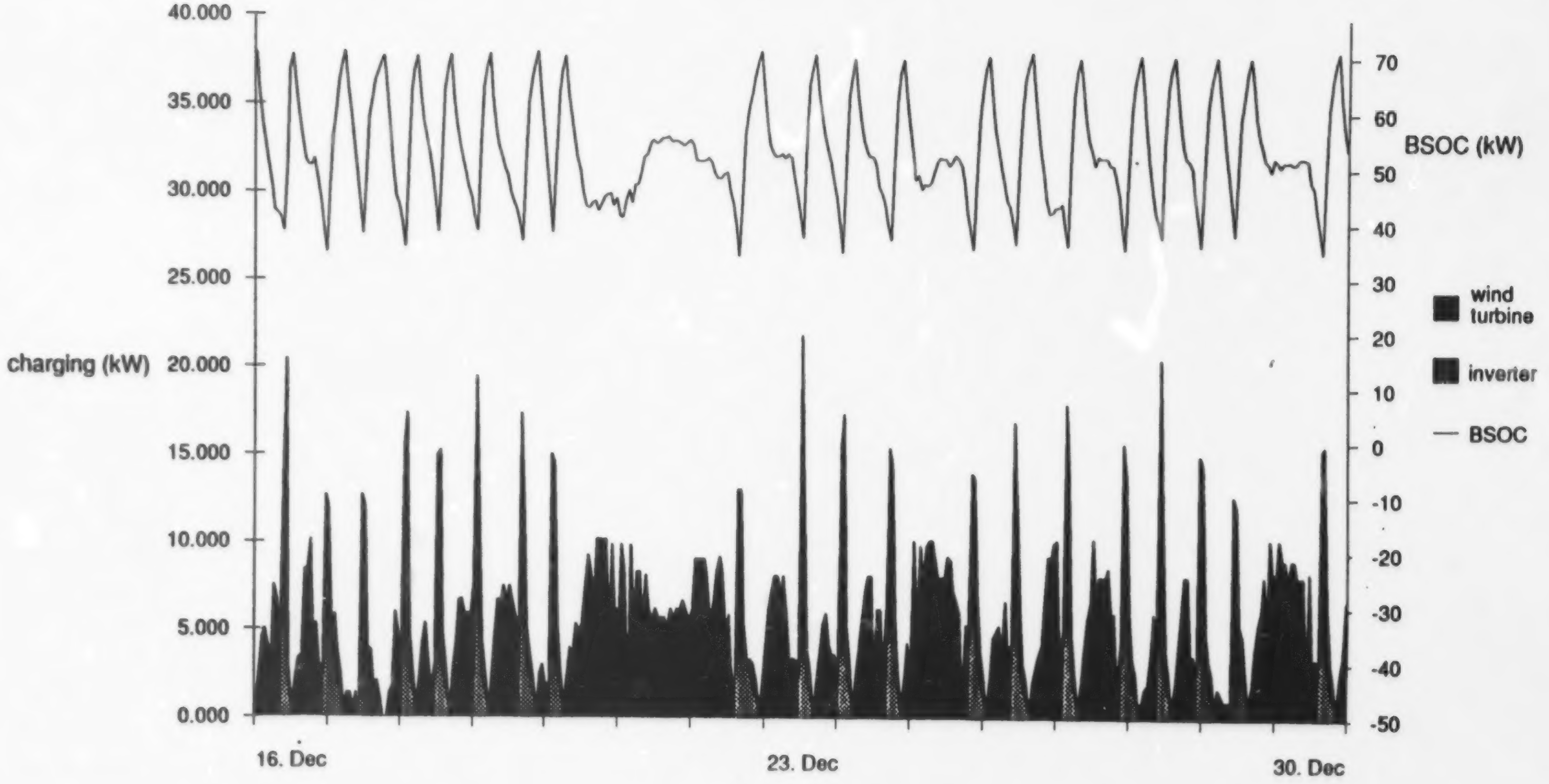
Hindcast Battery Charging History (1. Dec - 15. Dec)



December, 1989

based on 60% of actual loads

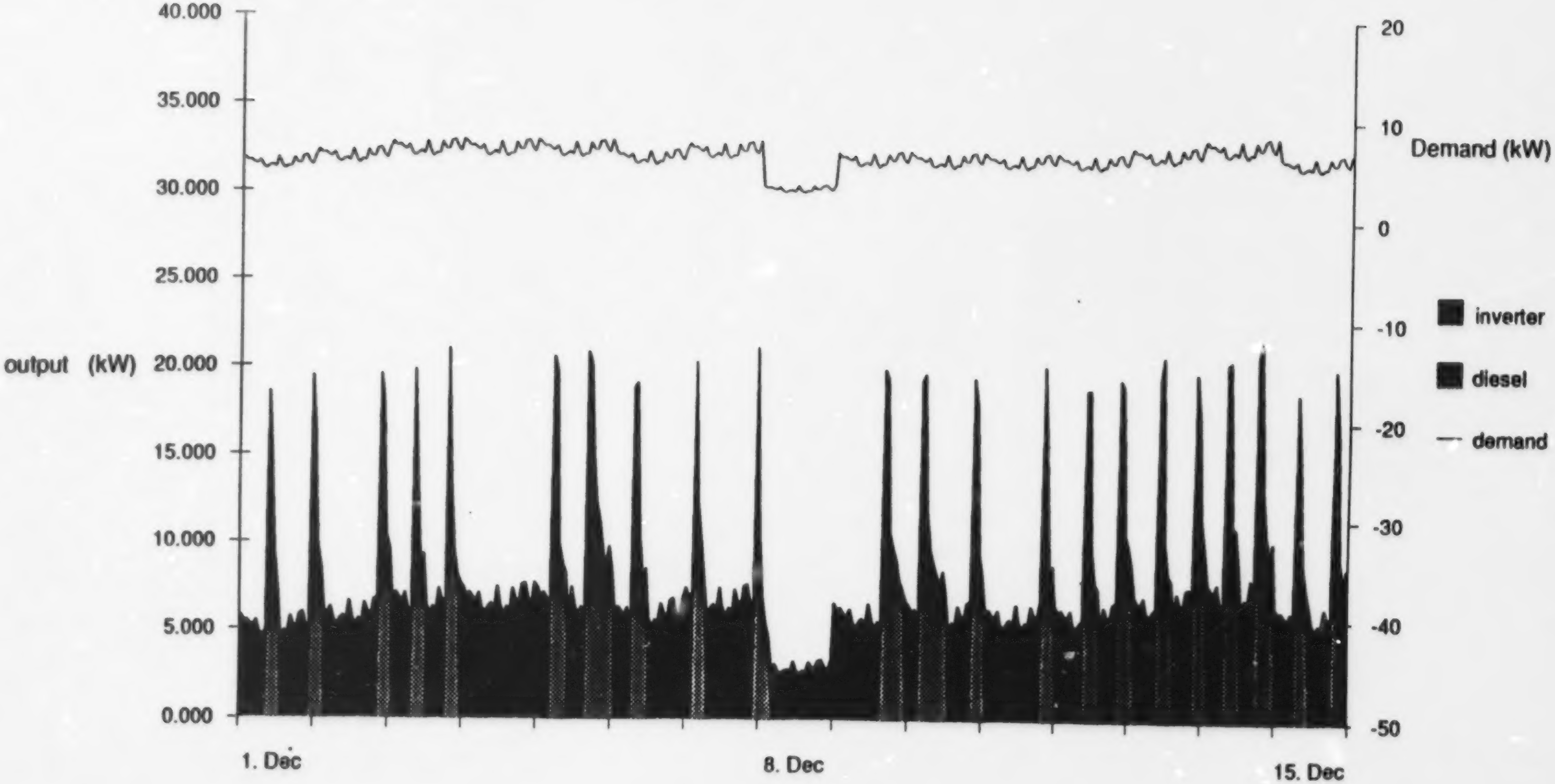
Hindcast Battery Charging History (16. Dec - 30. Dec)



December, 1989

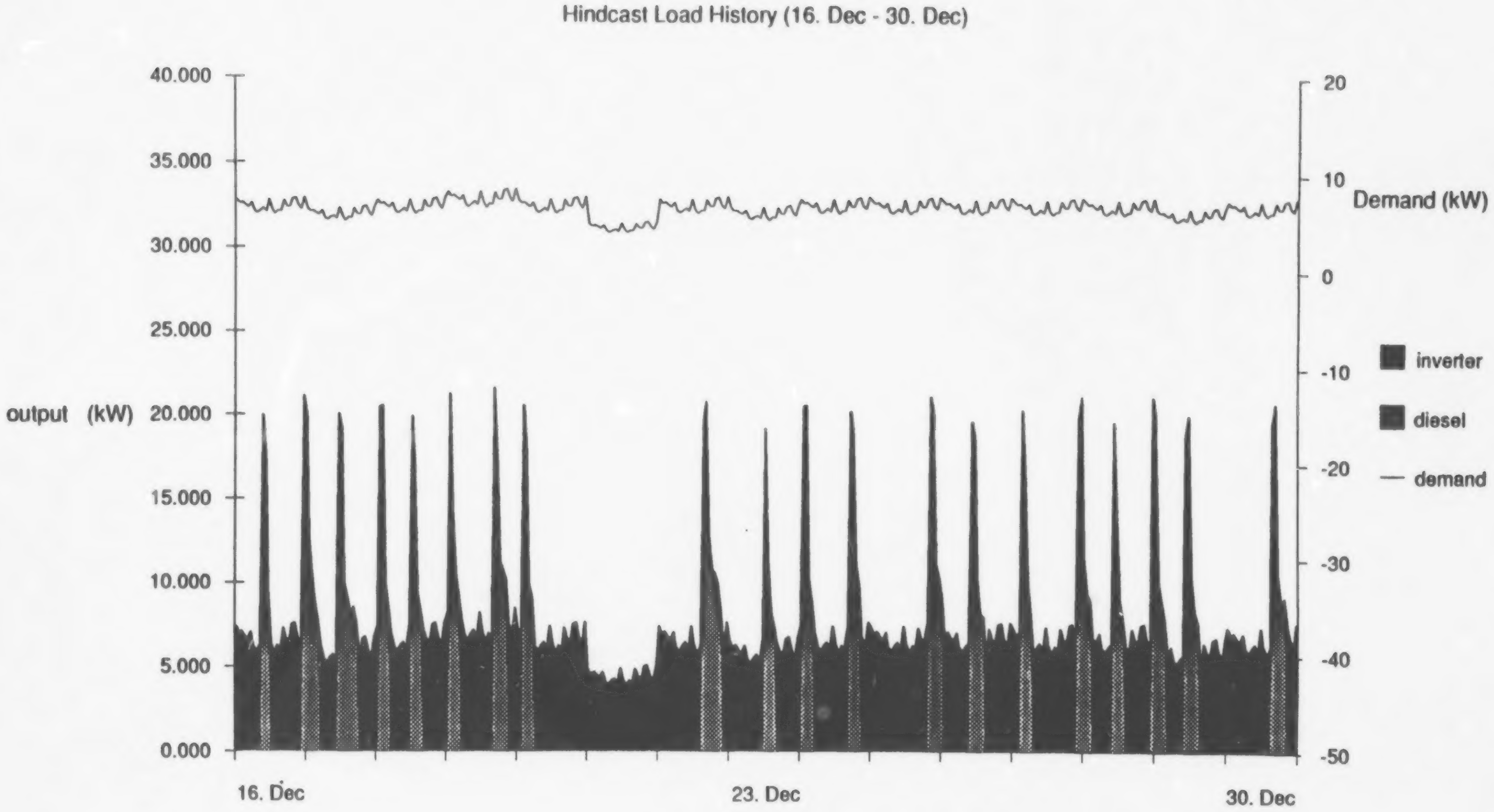
based on 60% of actual loads

Hindcast Load History (1. Dec - 15. Dec)



December, 1989

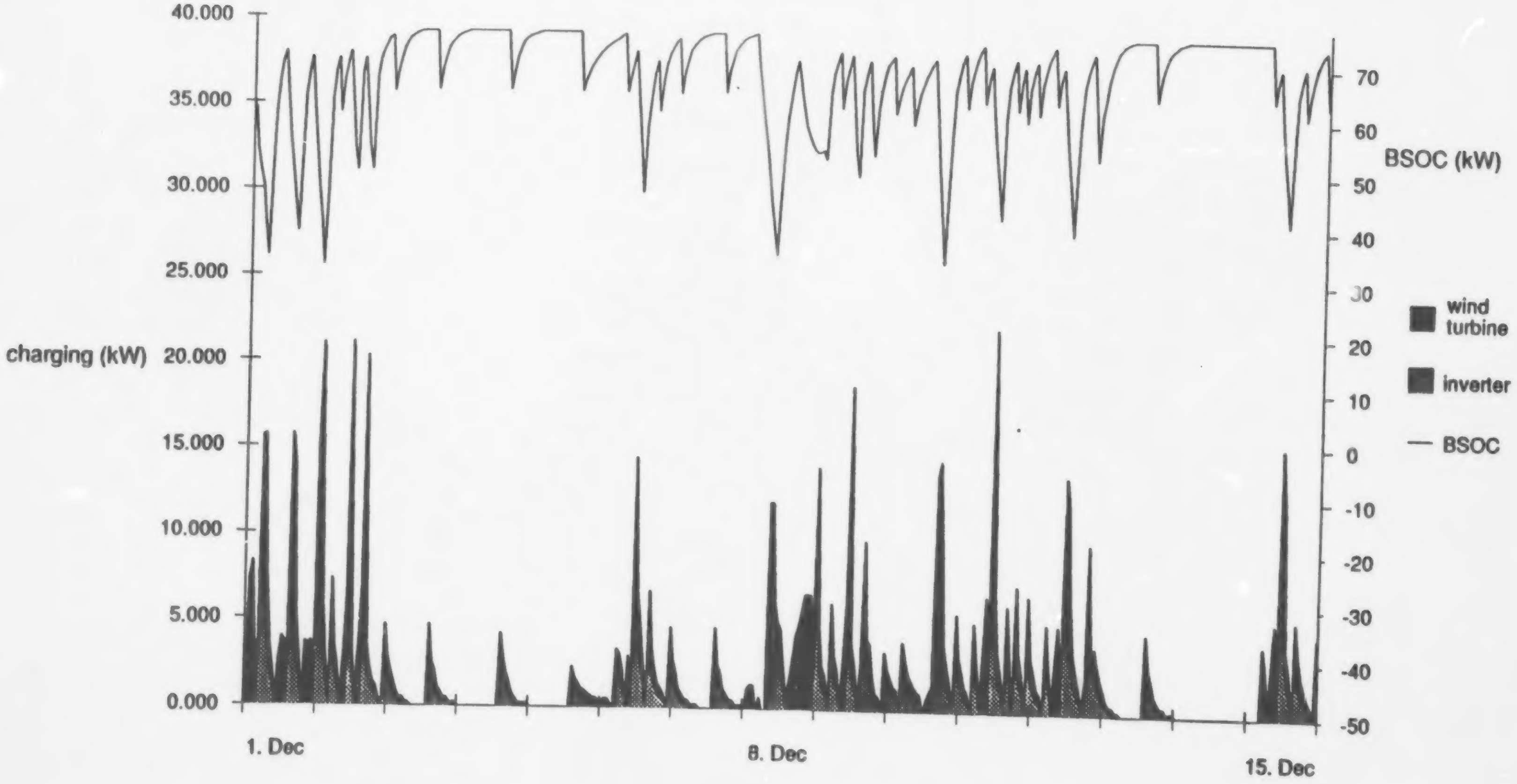
based on 60% of actual loads


Hindcast Load History (16. Dec - 30. Dec)

December, 1989

based on actual loads

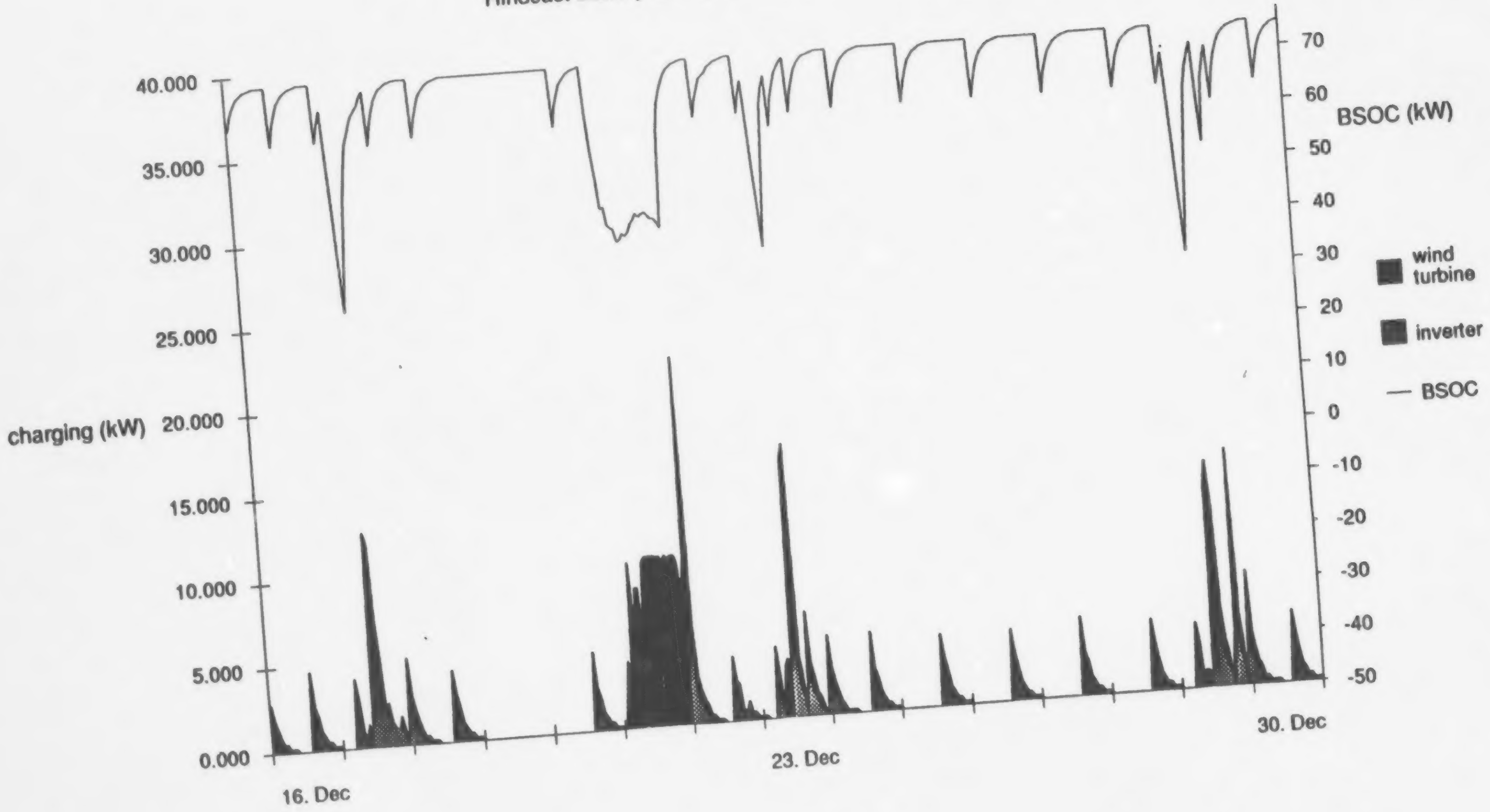
Hindcast Battery Charging History (1. Dec - 15. Dec)



December, 1989

based on actual loads

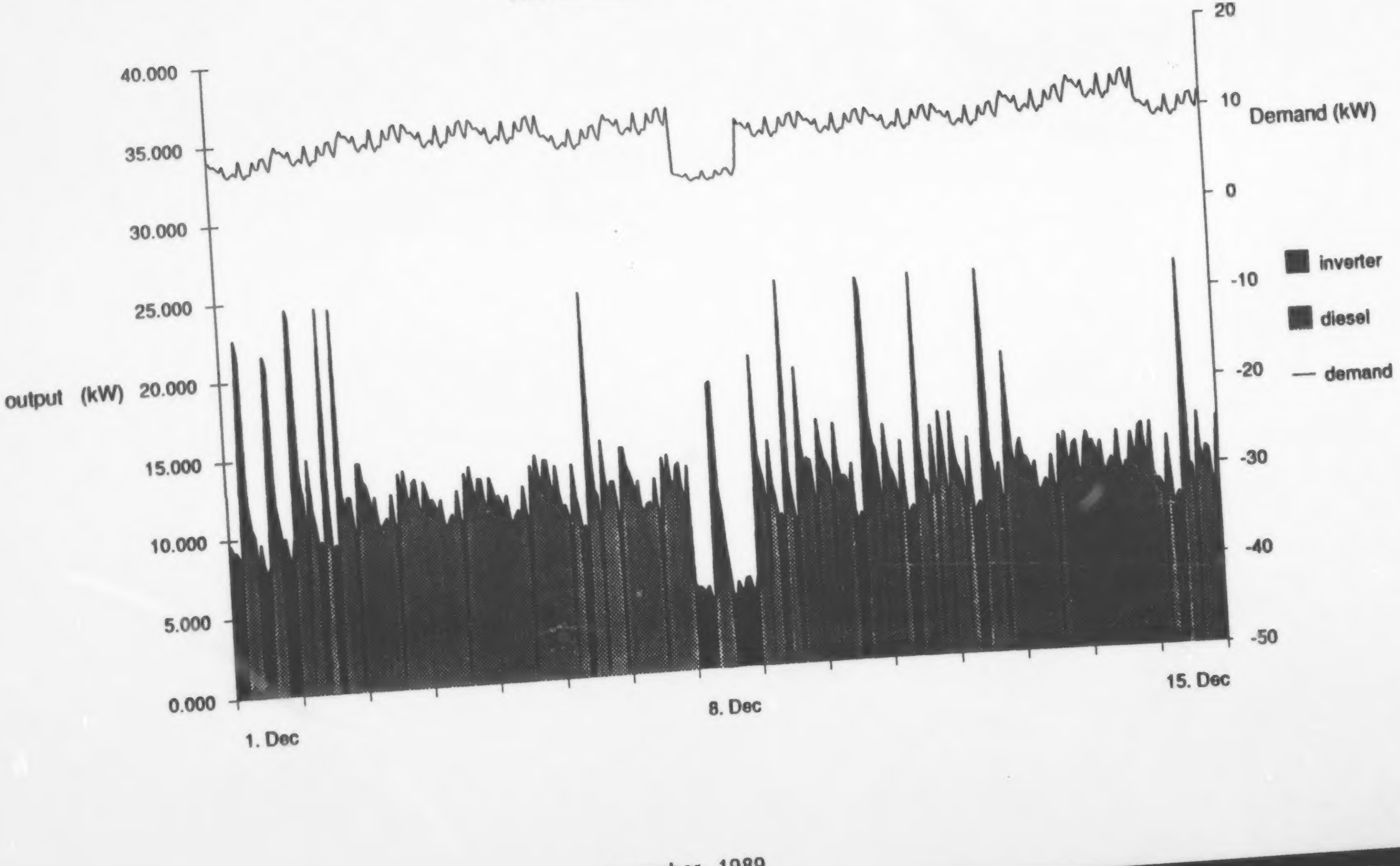
Hindcast Battery Charging History (16. Dec - 30. Dec)



December, 1989

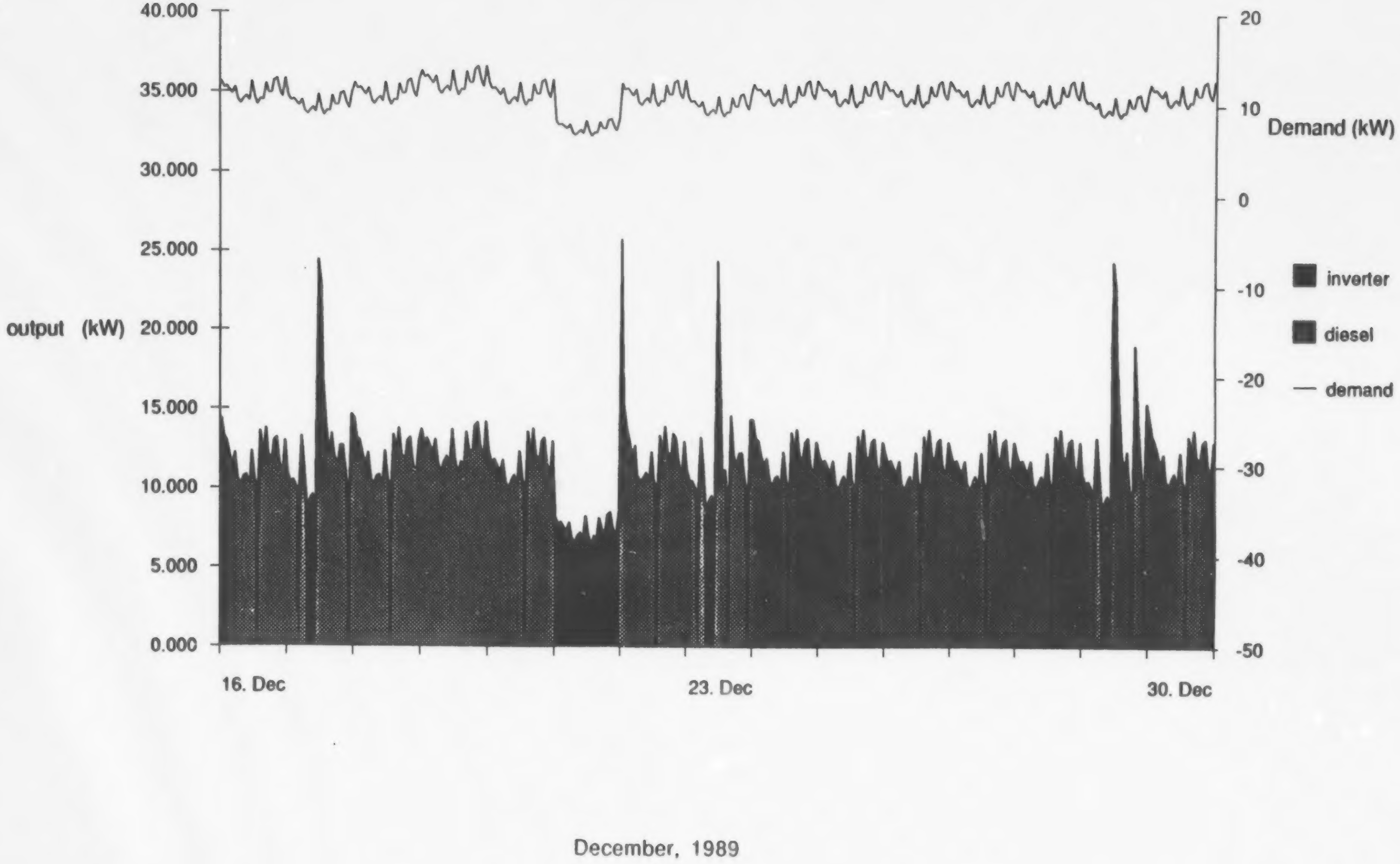
based on actual loads

Hindcast Load History (1. Dec - 15. Dec)



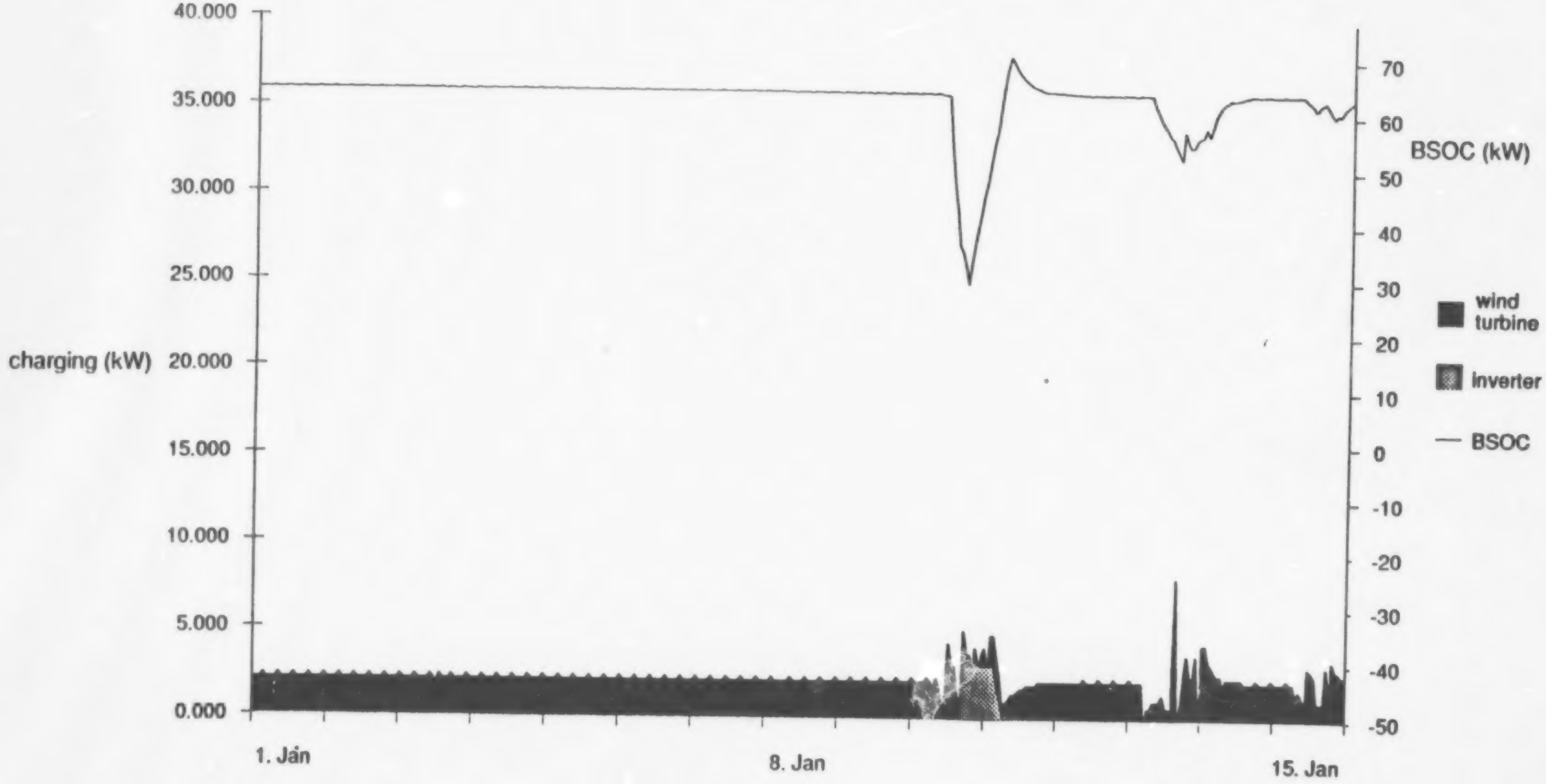
based on actual data

Hindcast Load History (16. Dec - 30. Dec)



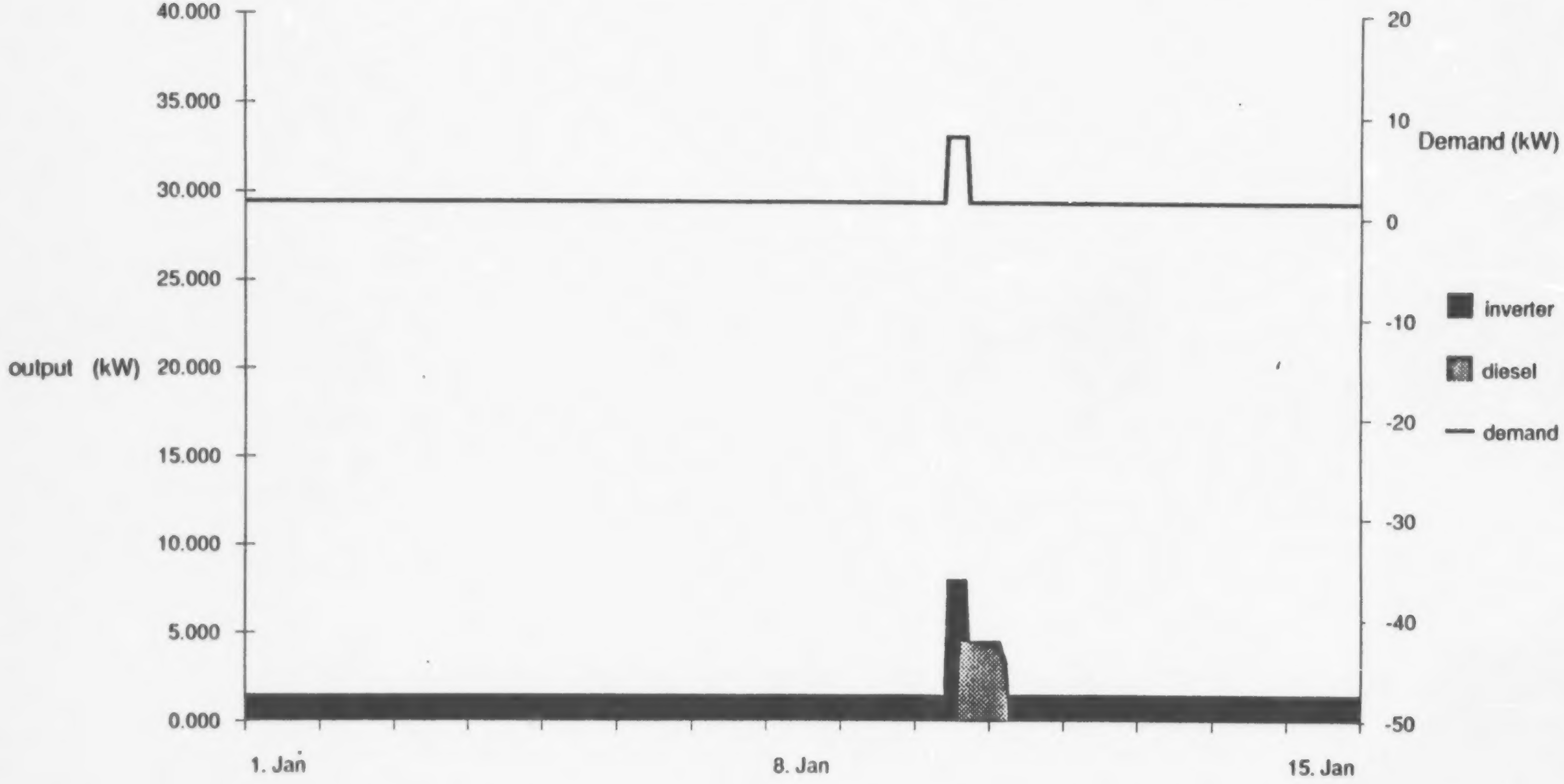
based on automatic station loads

Hindcast Battery Charging History (1. Jan - 15. Jan)



January, 1990

based on automatic station loads

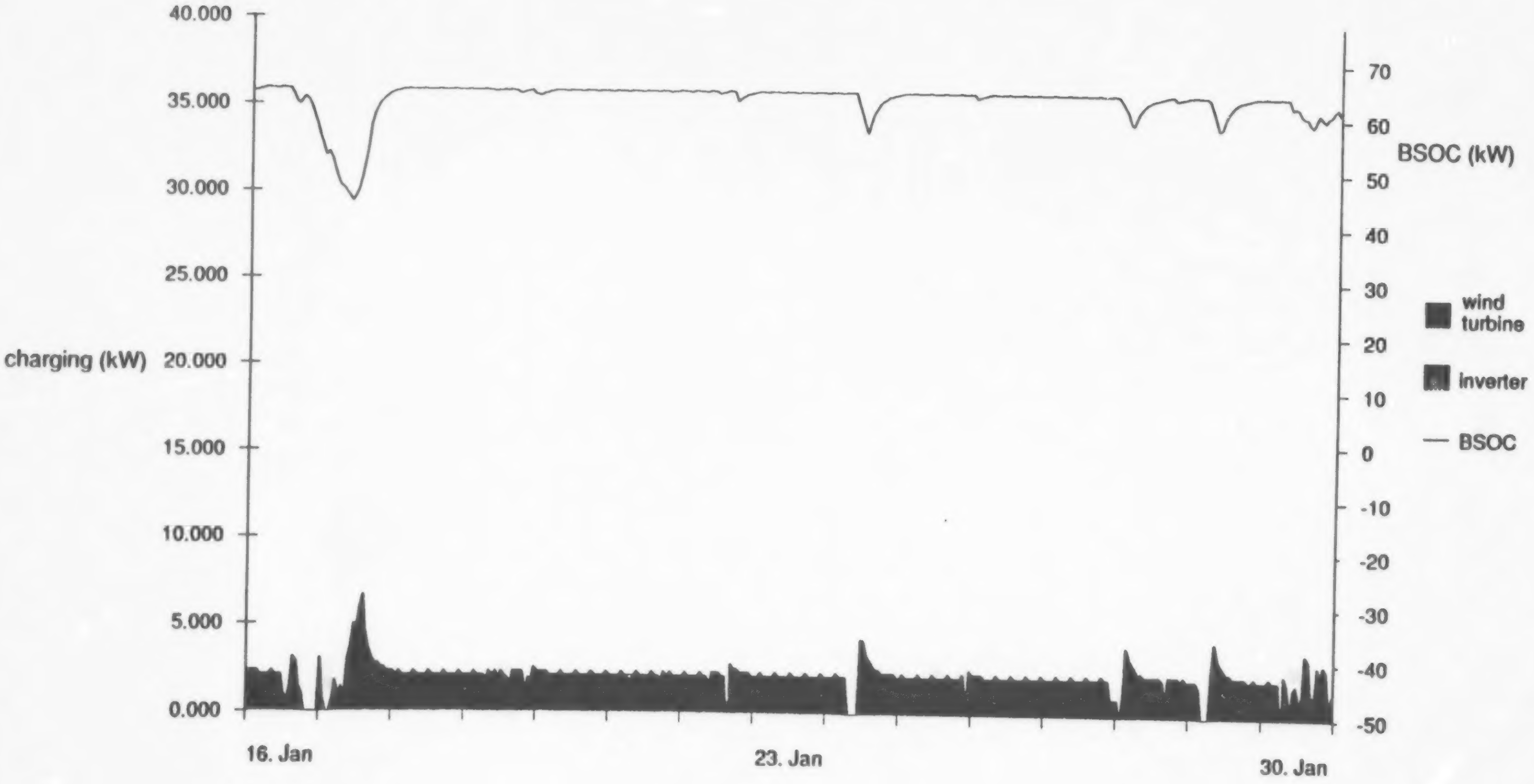


Hindcast Load History (1. Jan - 15. Jan)

January, 1990

based on automatic station loads

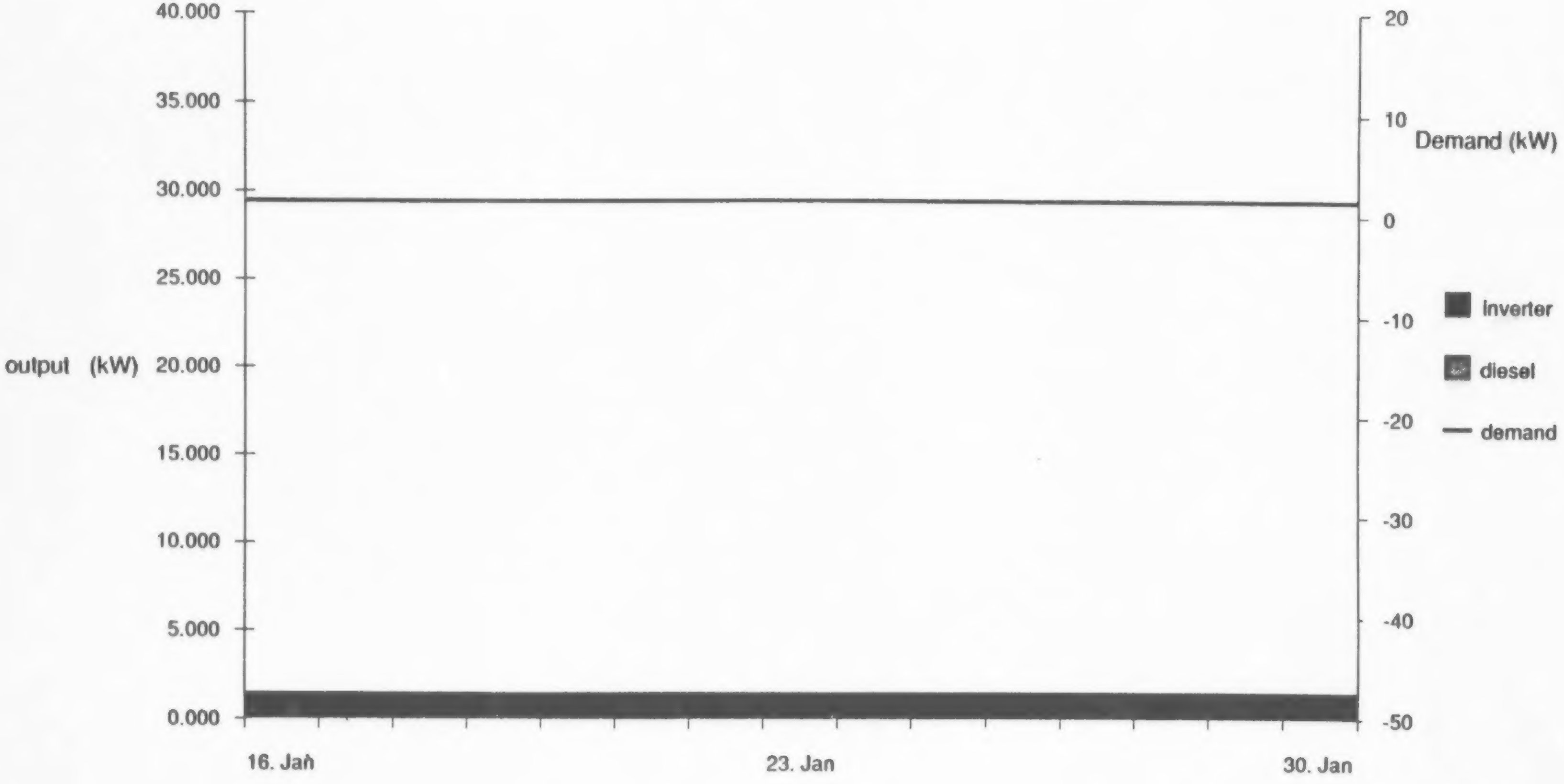
Hindcast Battery Charging History (16. Jan - 30. Jan)



January, 1990

based on automatic station loads

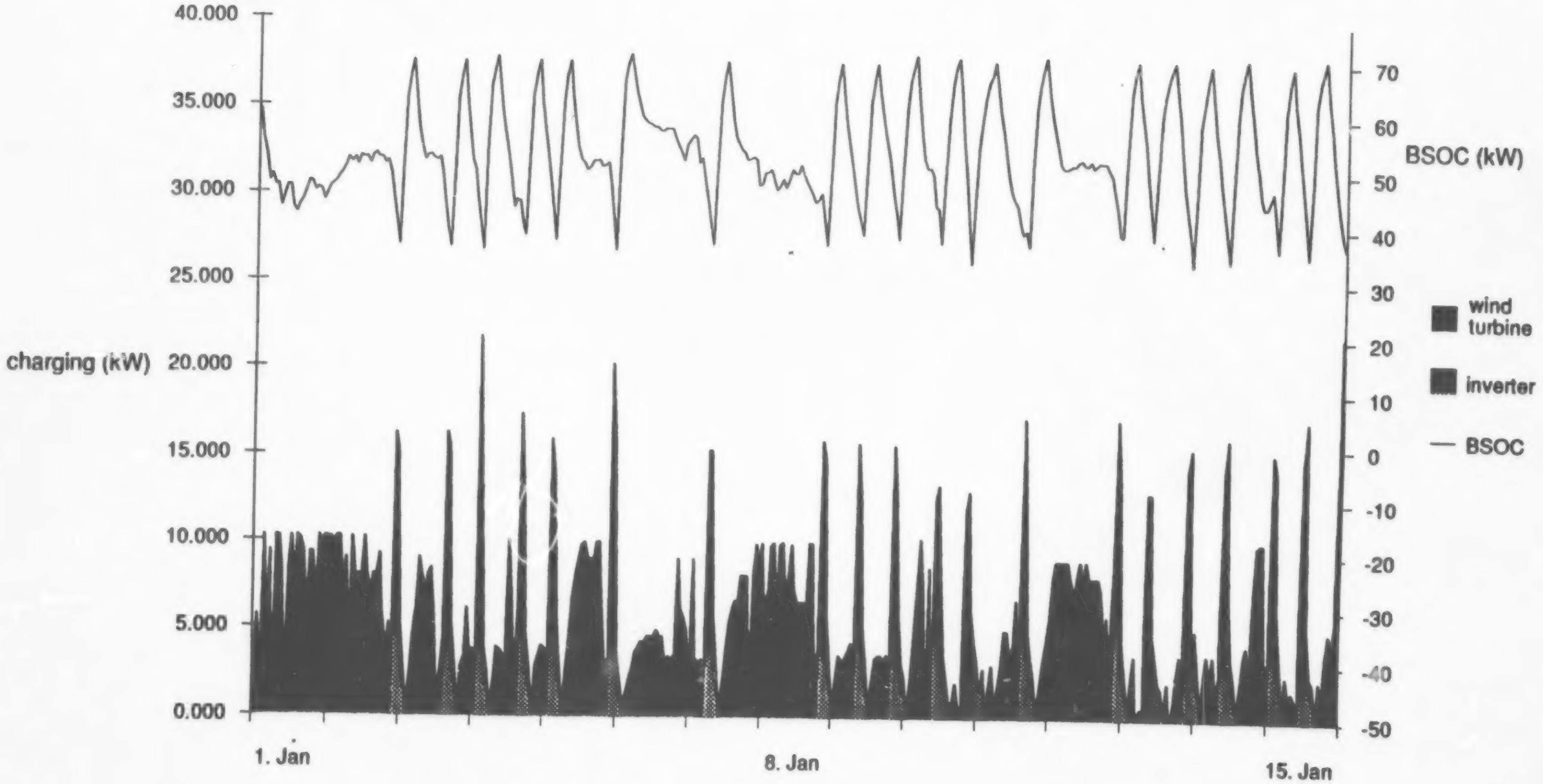
Hindcast Load History (16. Jan - 30. Jan)



January, 1990

based on 60% of actual loads

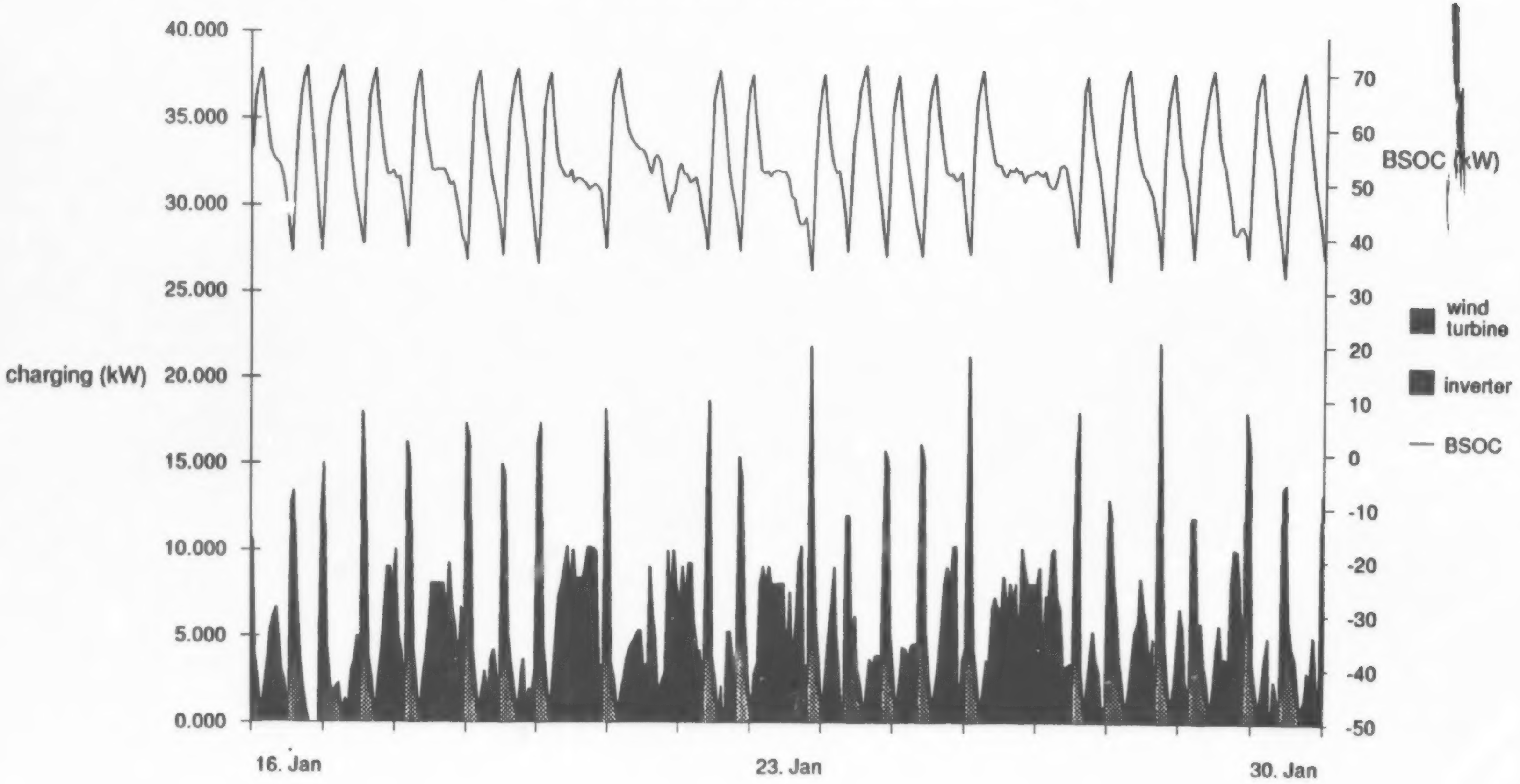
Hindcast Battery Charging History (1. Jan - 15. Jan)



January, 1990

based on 60% of actual loads

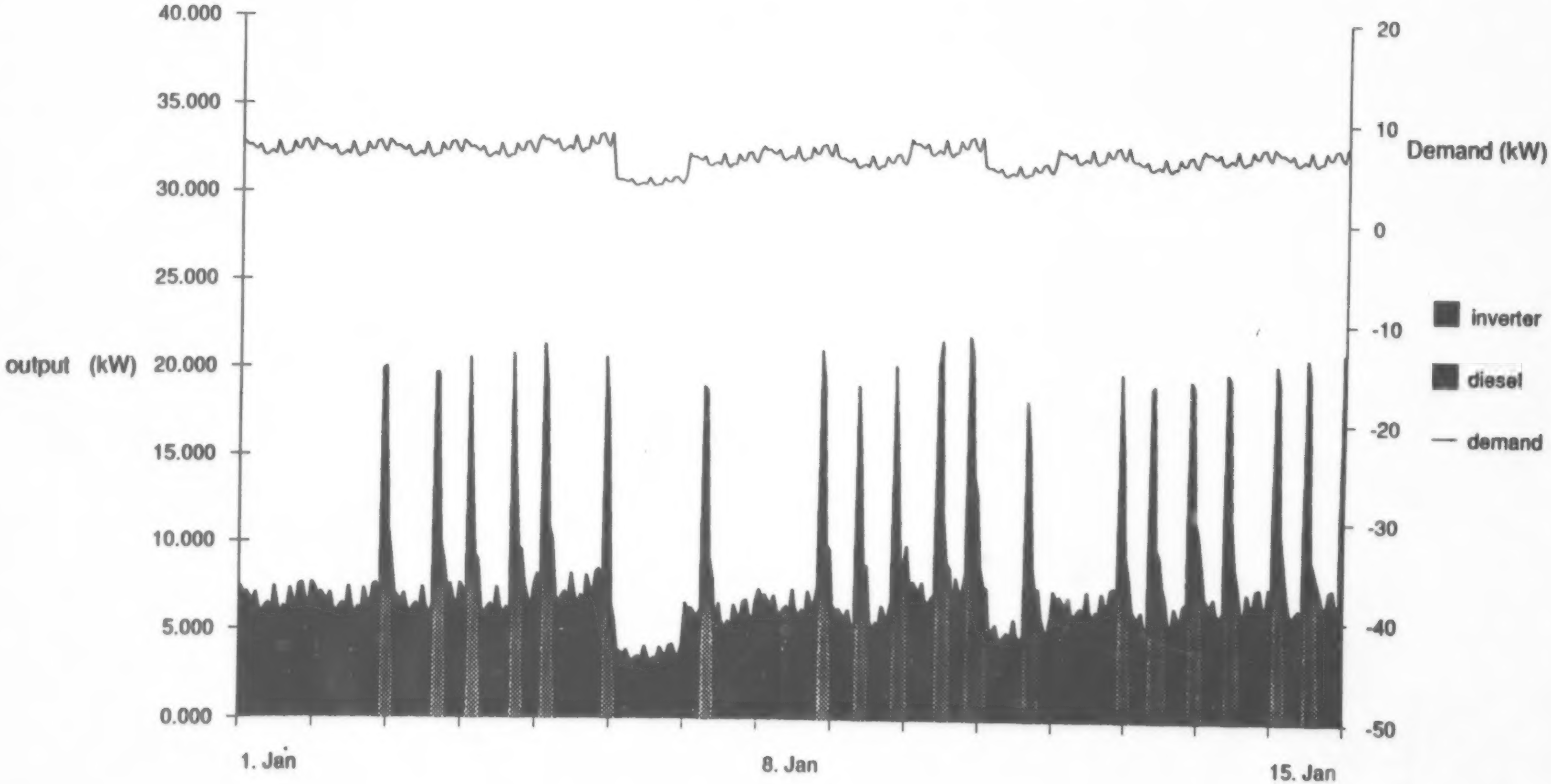
Hindcast Battery Charging History (16. Jan - 30. Jan)



January, 1990

based on 60% of actual loads

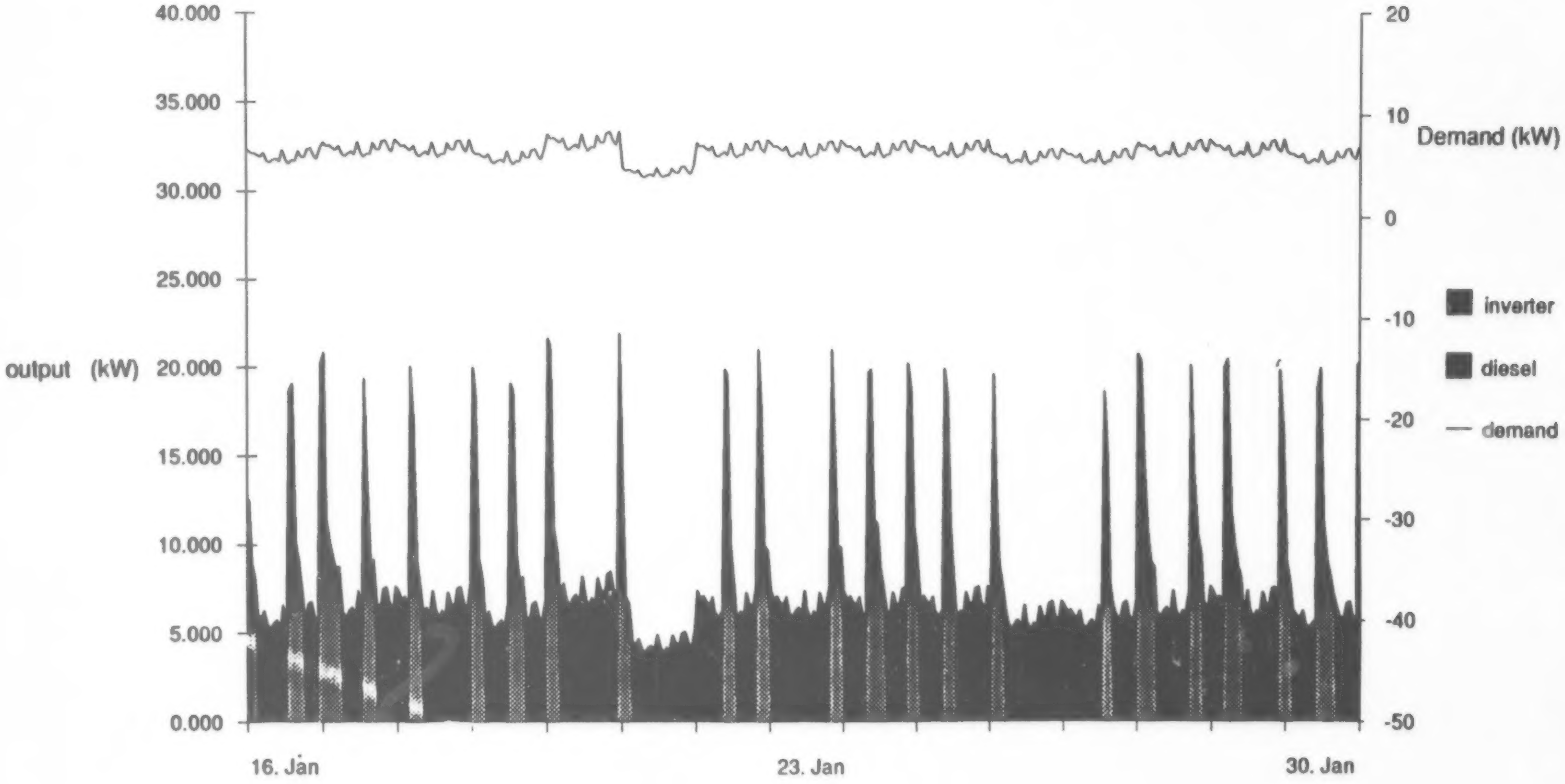
Hindcast Load History (1. Jan - 15. Jan)



January, 1990

based on 60% of actual loads

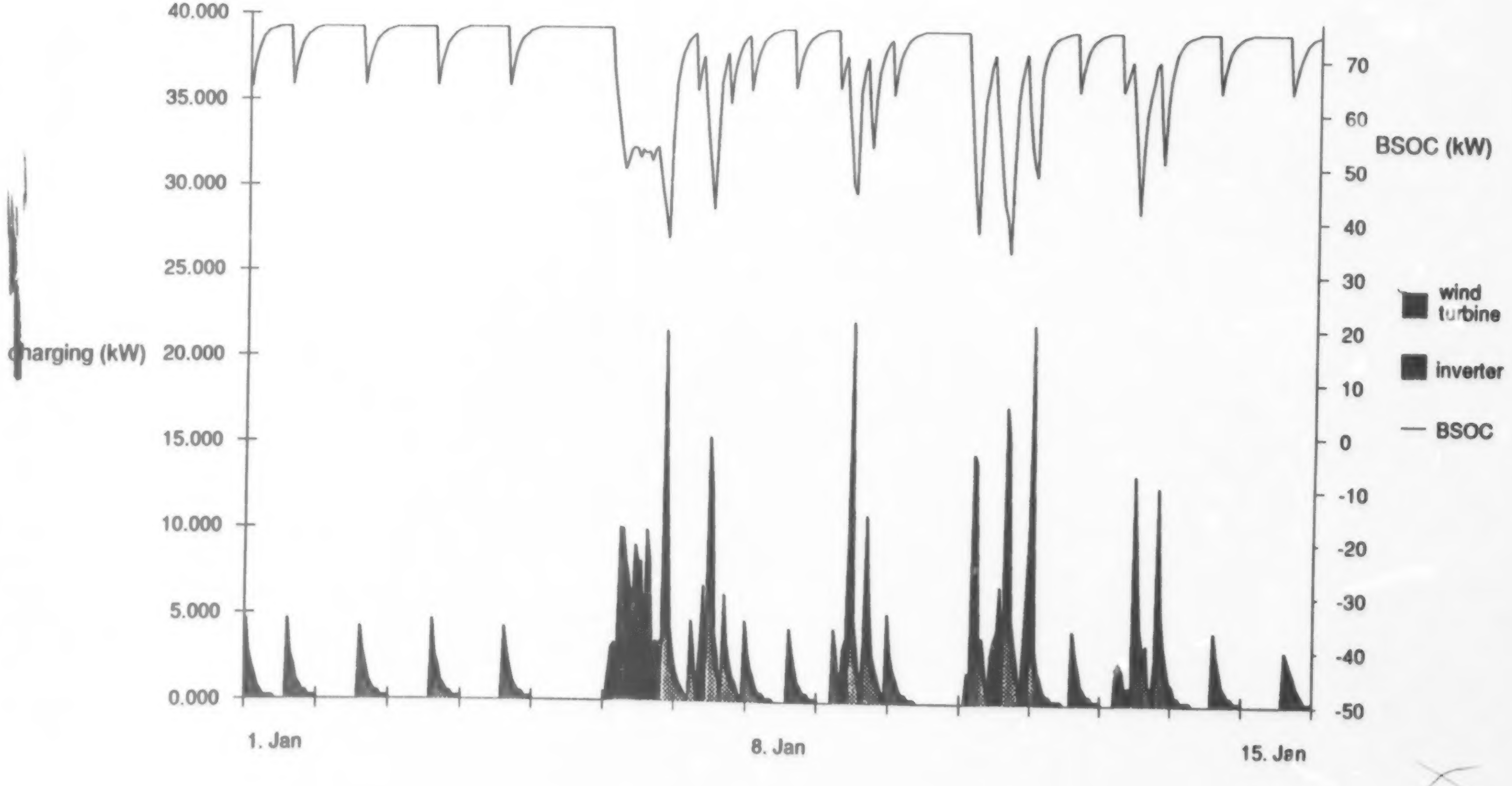
Hindcast Load History (16. Jan - 30. Jan)



January, 1990

based on actual loads

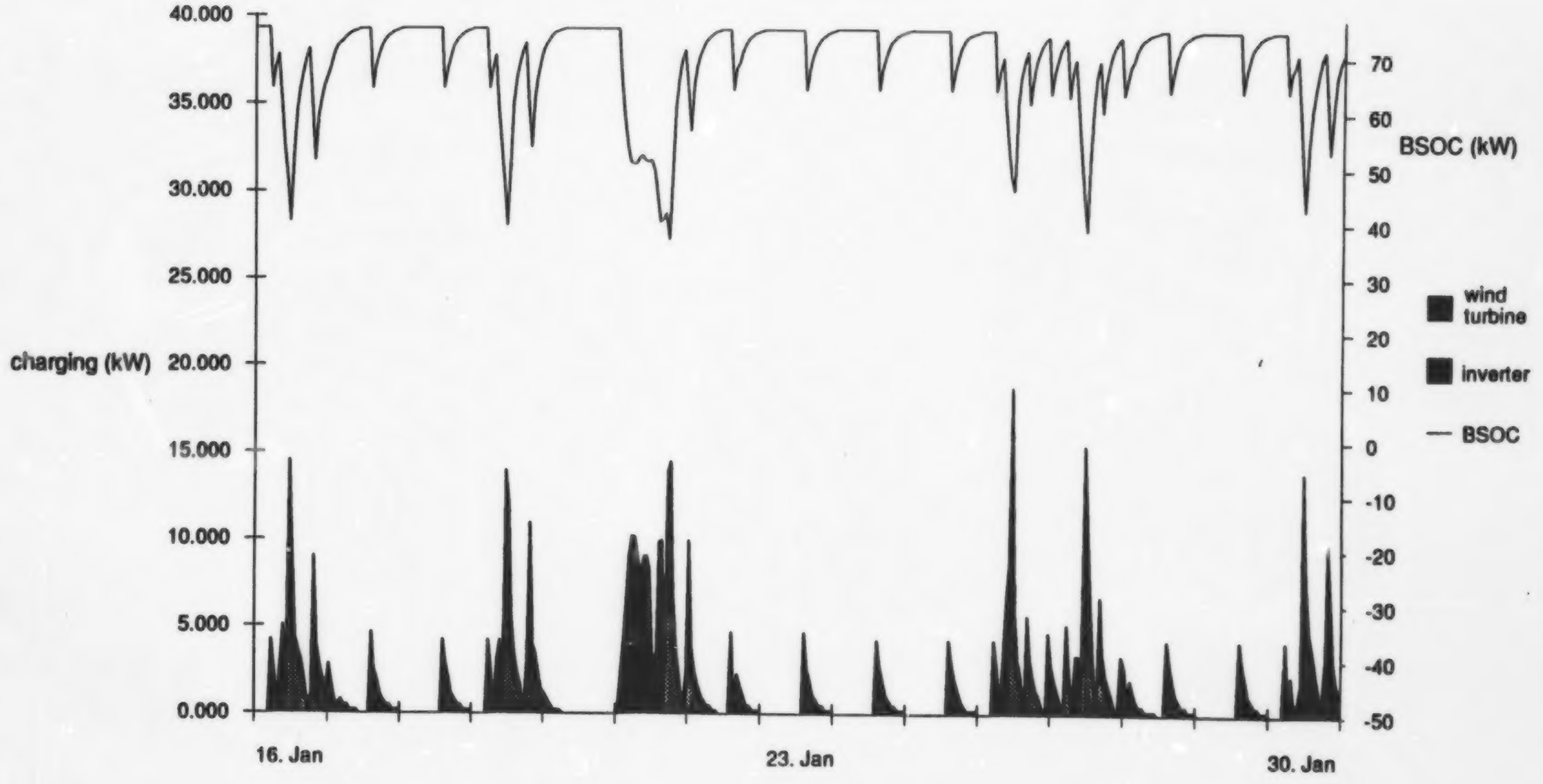
Hindcast Battery Charging History (1. Jan - 15. Jan)



January, 1990

based on actual loads

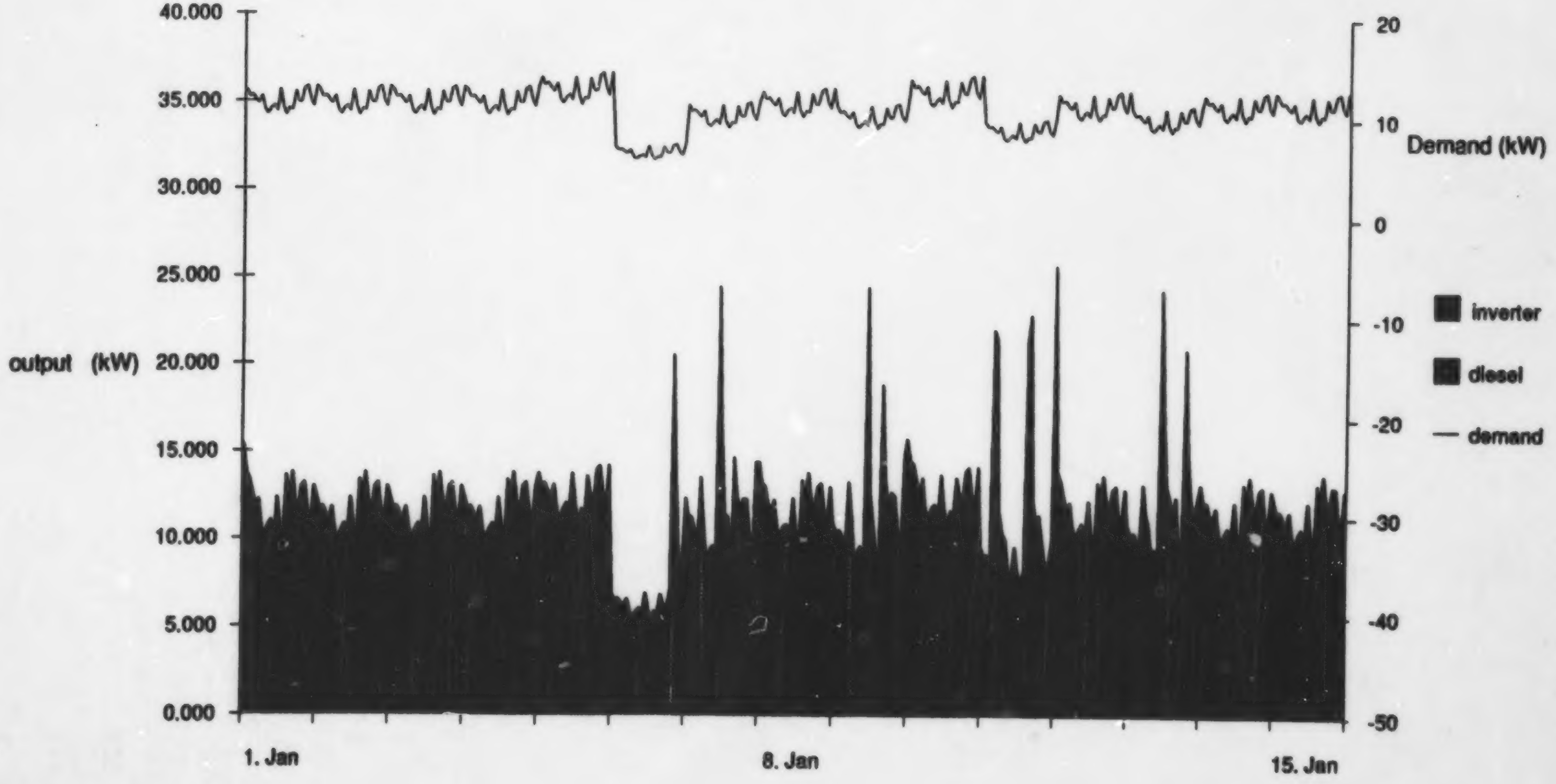
Hindcast Battery Charging History (16. Jan - 30. Jan)



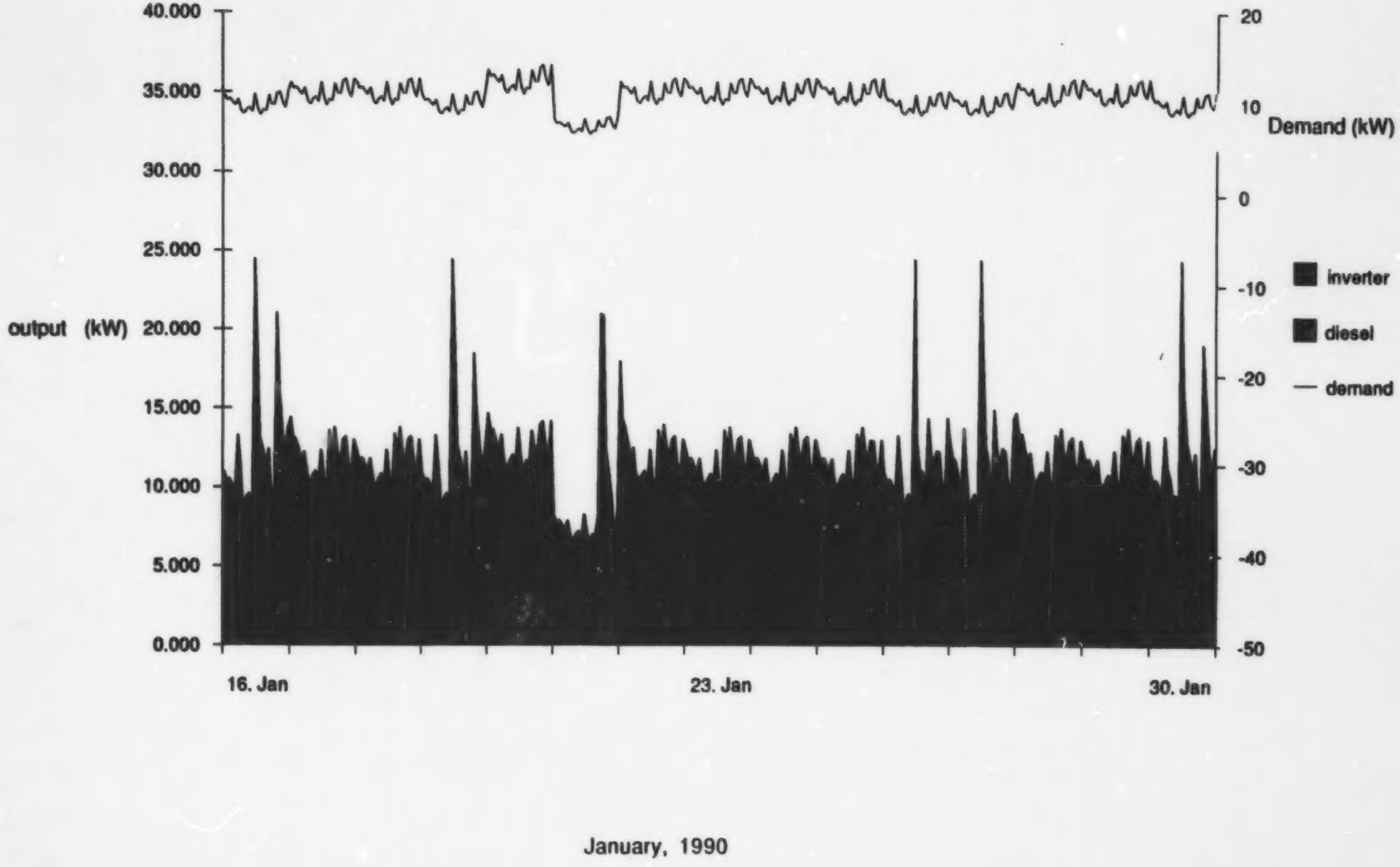
January, 1990

based on actual loads

Hindcast Load History (1. Jan - 15. Jan)



January, 1990

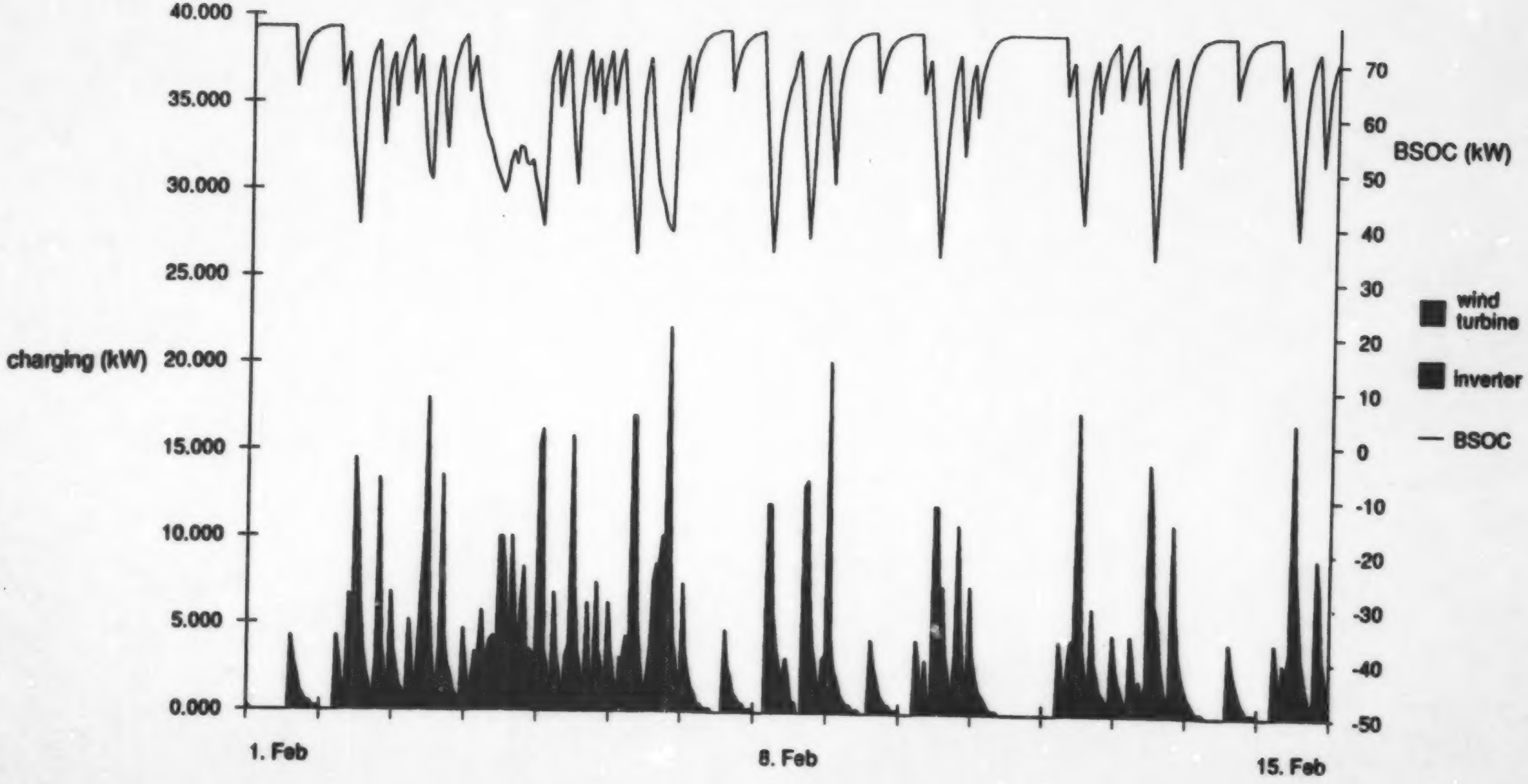


based on actual loads

Hindcast Load History (16. Jan - 30. Jan)

based on actual loads

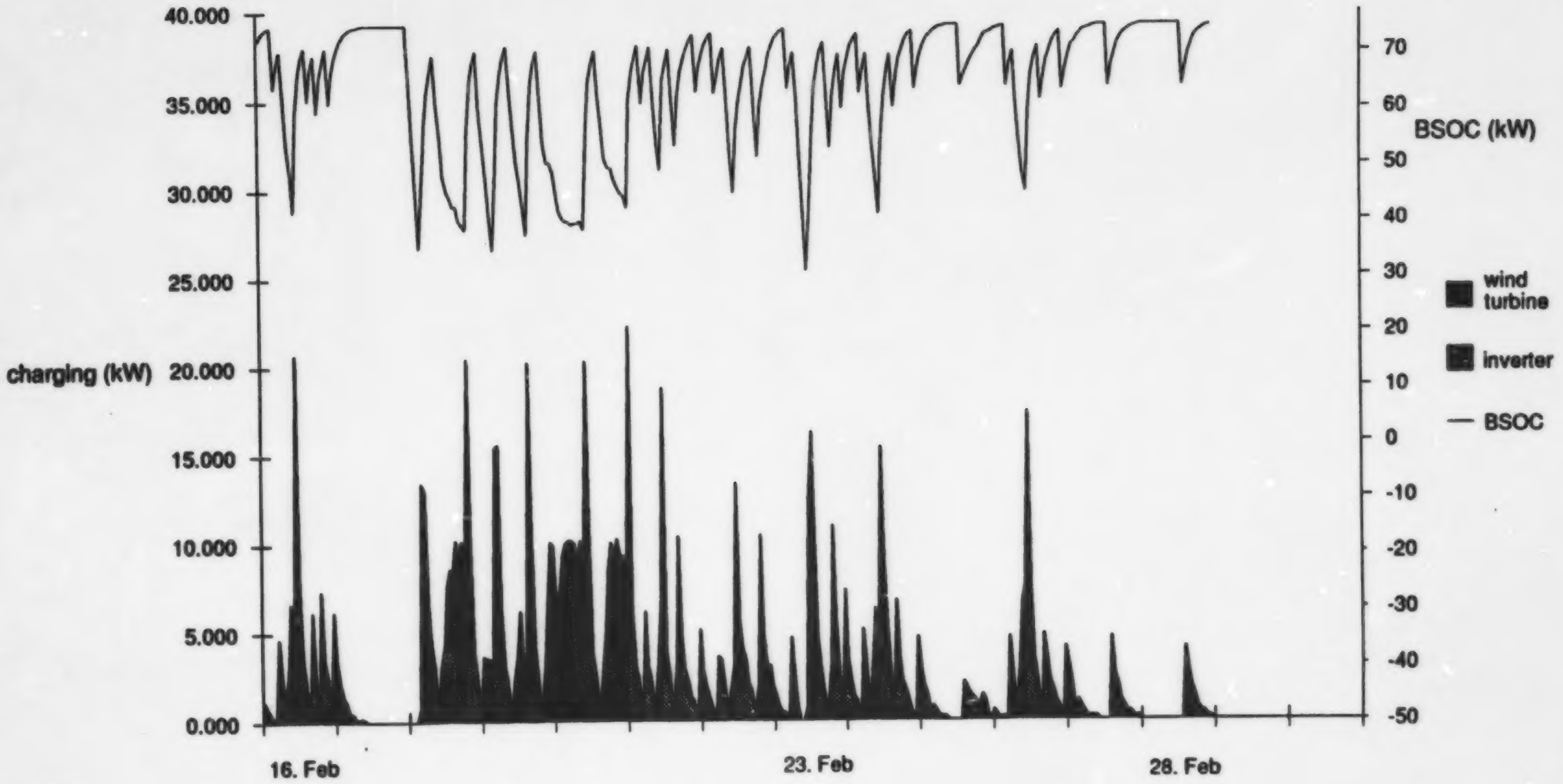
Hindcast Battery Charging History (1. Feb - 15. Feb)



February, 1990

based on actual loads

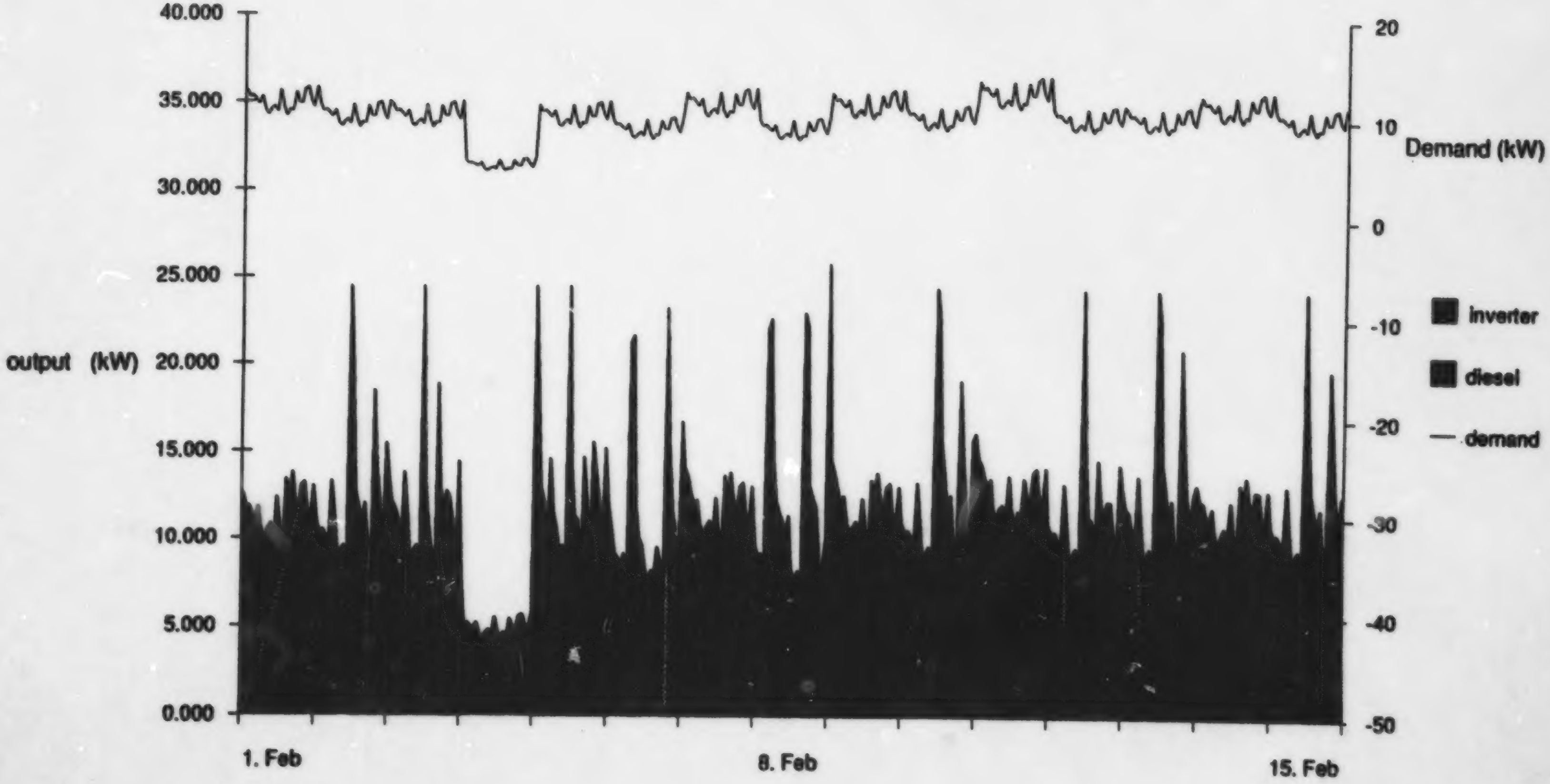
Hindcast Battery Charging History (16. Feb - 28. Feb)



February, 1990

based on actual loads

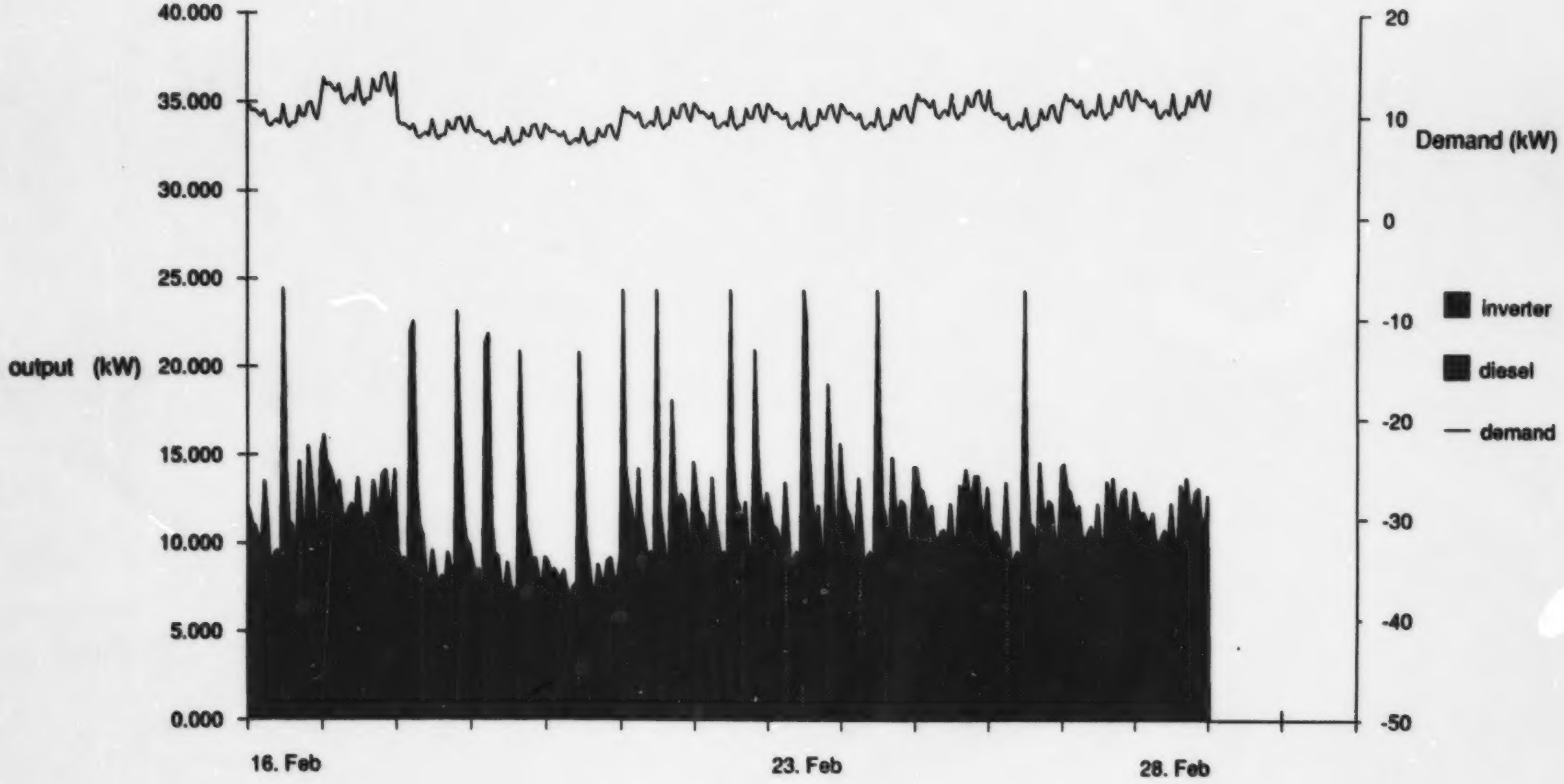
Hindcast Load History (1. Feb - 15. Feb)



February, 1990

based on actual loads

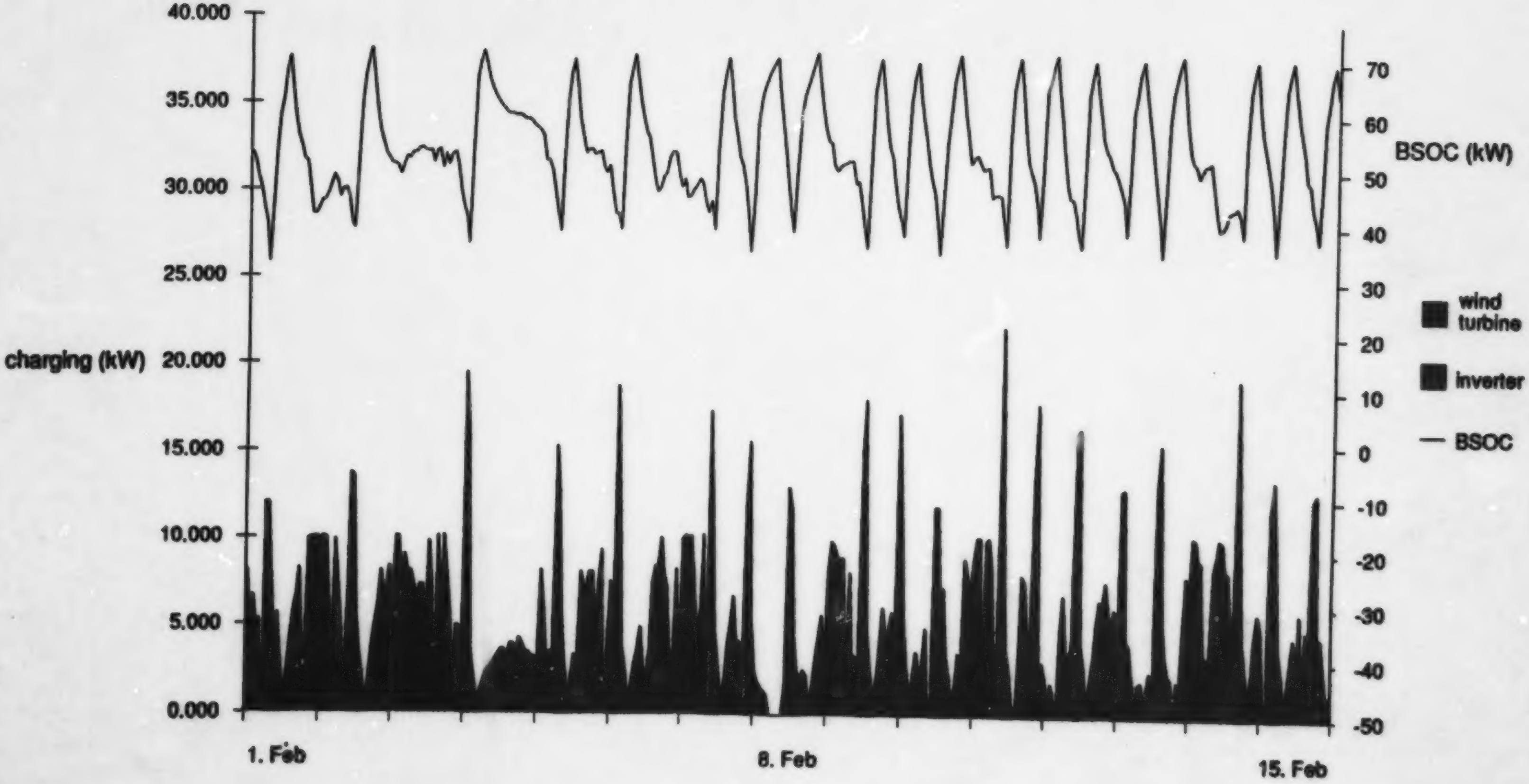
Hindcast Load History (16. Feb - 28. Feb)



February, 1990

based on 60% of actual loads

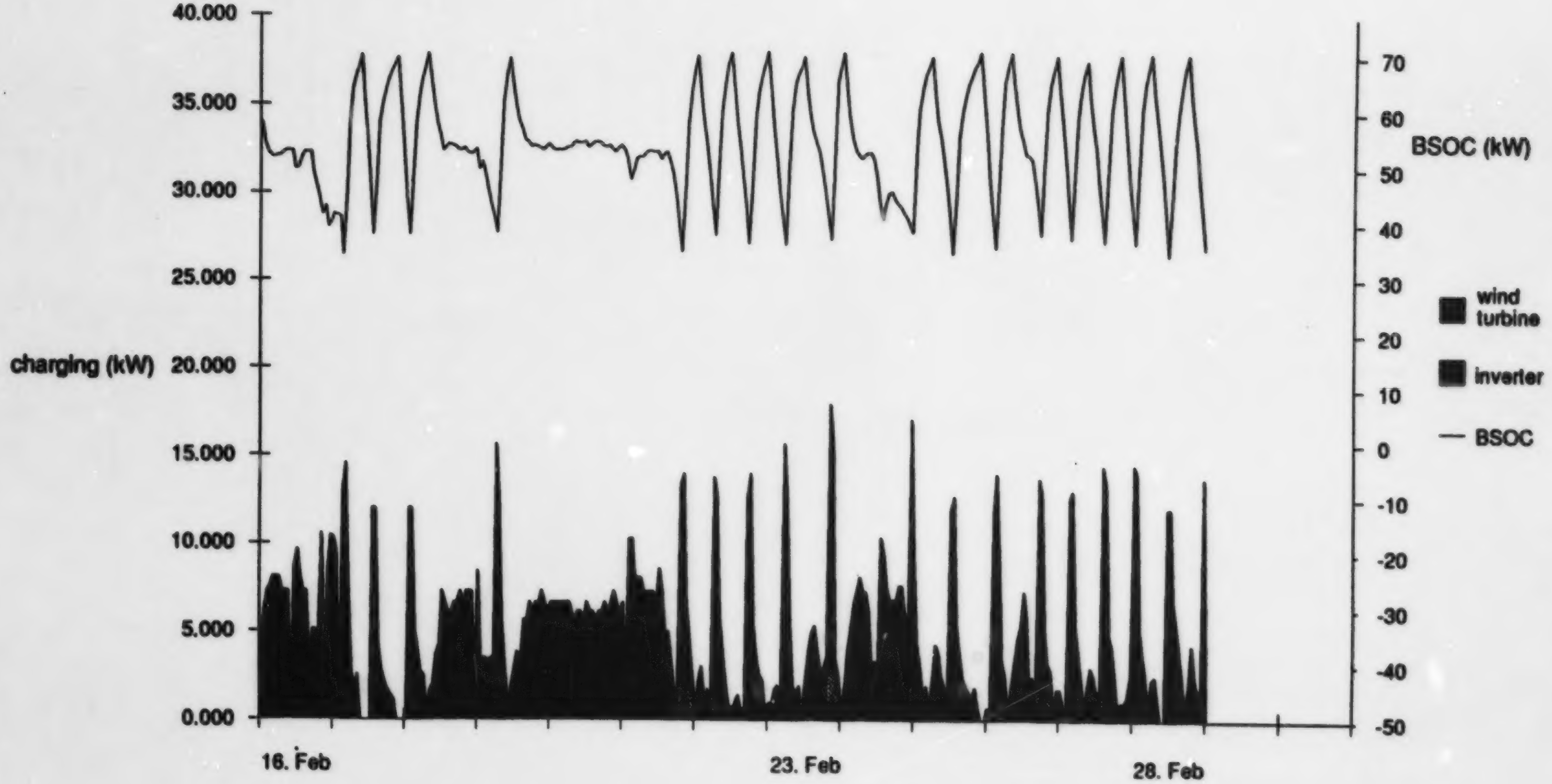
Hindcast Battery Charging History (1. Feb - 15. Feb)



February, 1990

based on 60% of actual loads

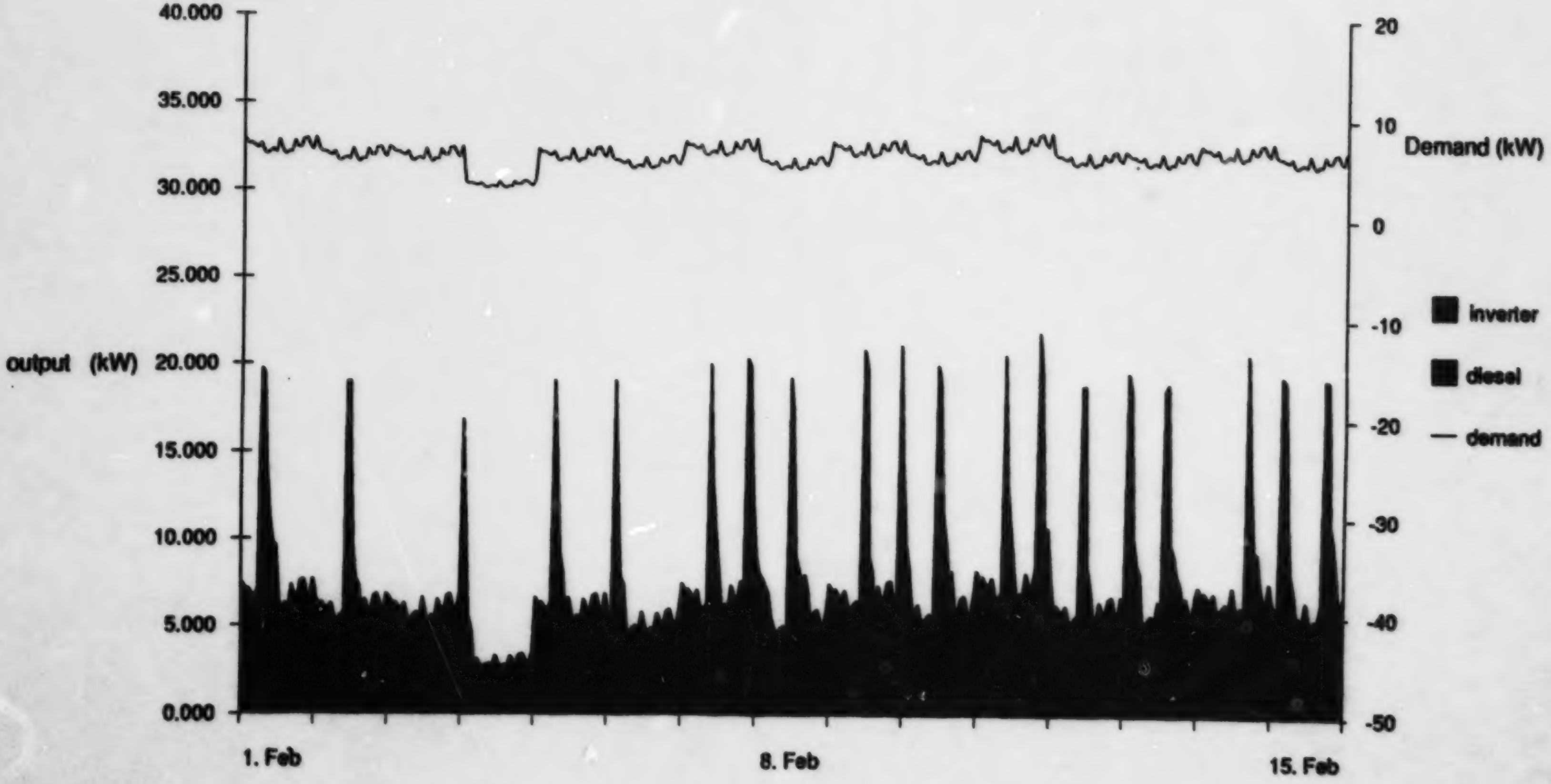
Hindcast Battery Charging History (16. Feb - 28. Feb)



February, 1990

based on 60% of actual loads

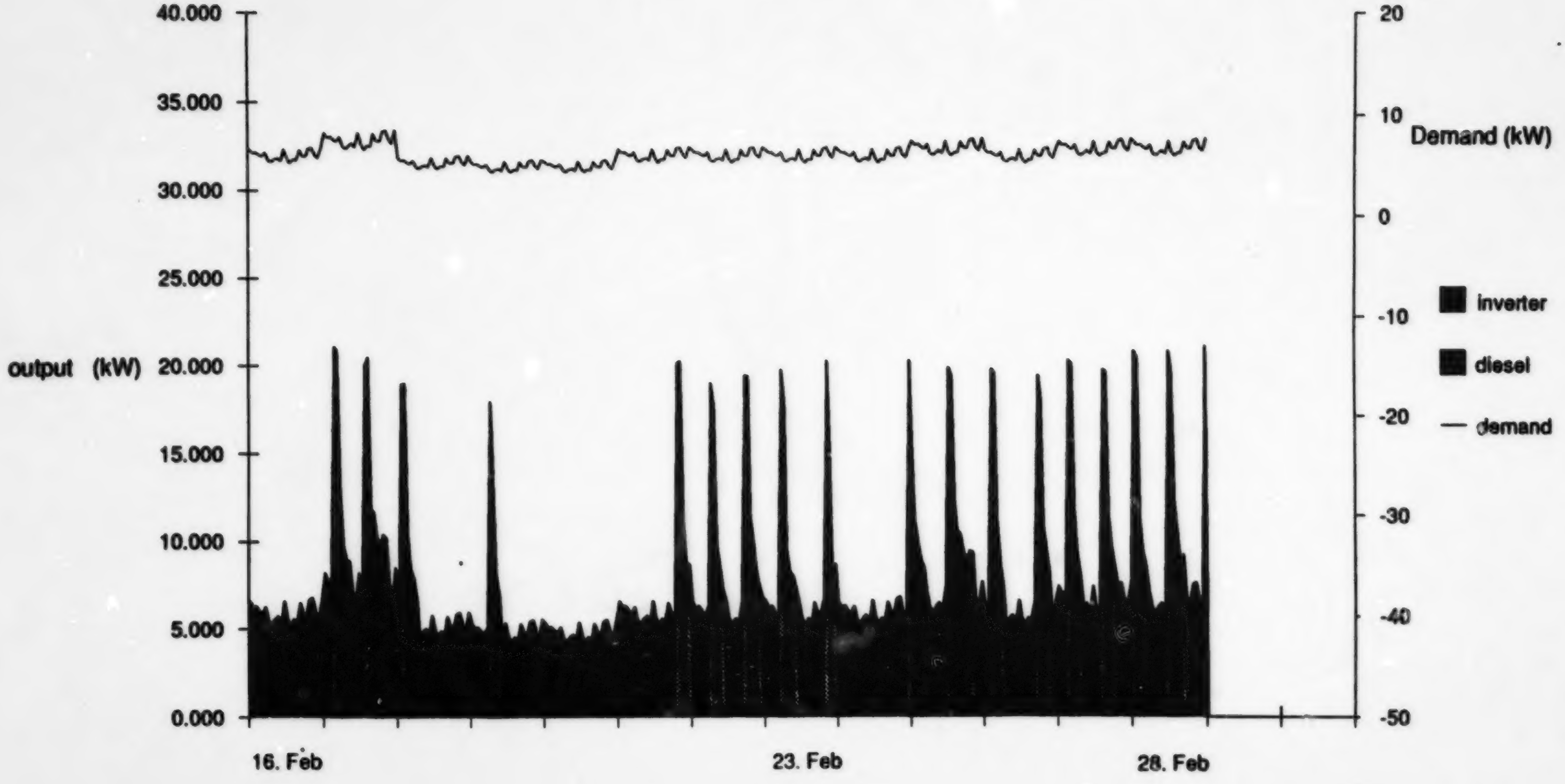
Hindcast Load History (1. Feb - 15. Feb)



February, 1990

based on 60% of actual loads

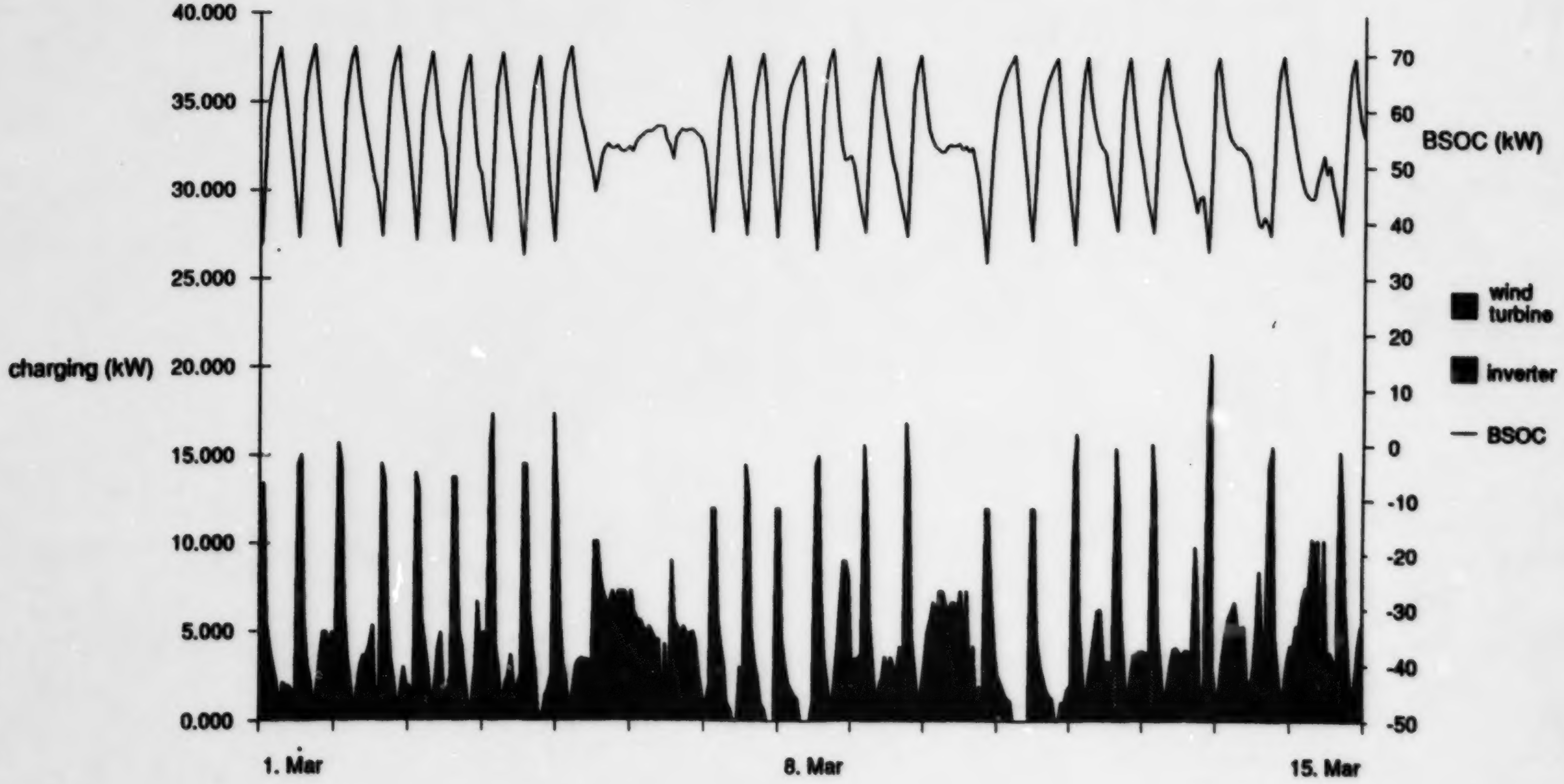
Hindcast Load History (16. Feb - 28. Feb)



February. 1990

based on 60% of actual loads

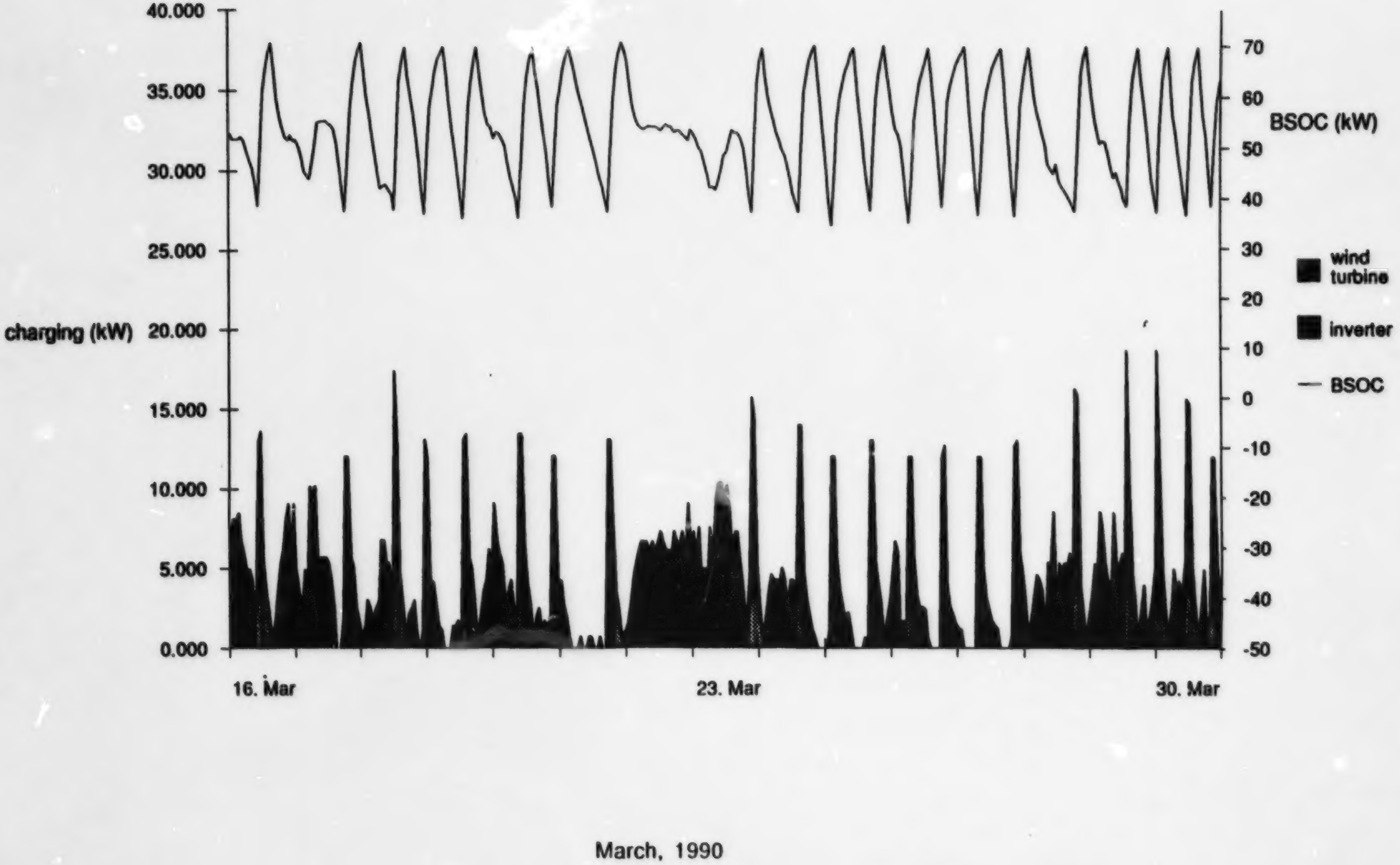
Hindcast Battery Charging History (1. Mar - 15. Mar)



March, 1990

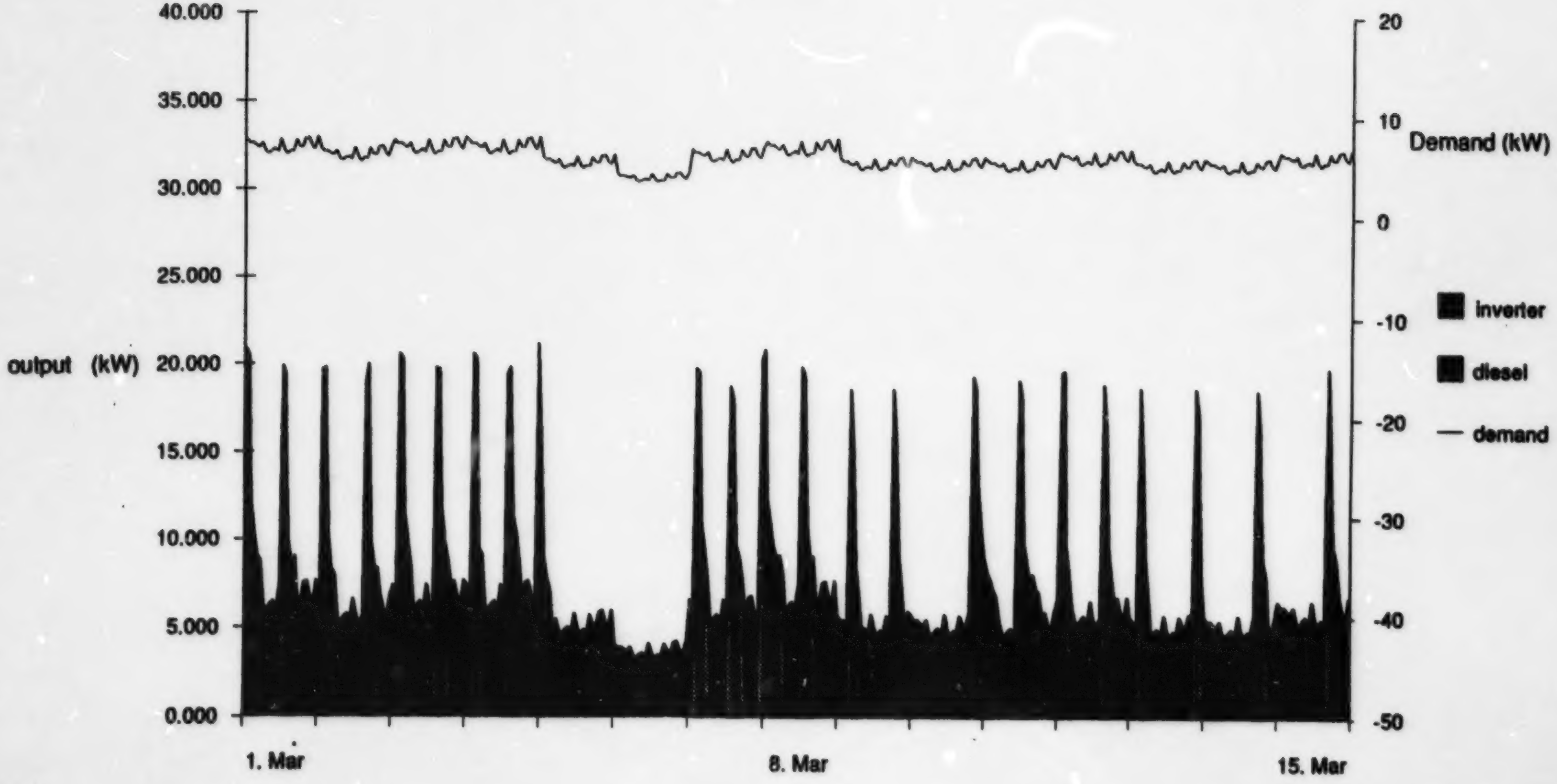
based on 60% of actual loads

Hindcast Battery Charging History (16. Mar - 30. Mar)



based on 60% of actual loads

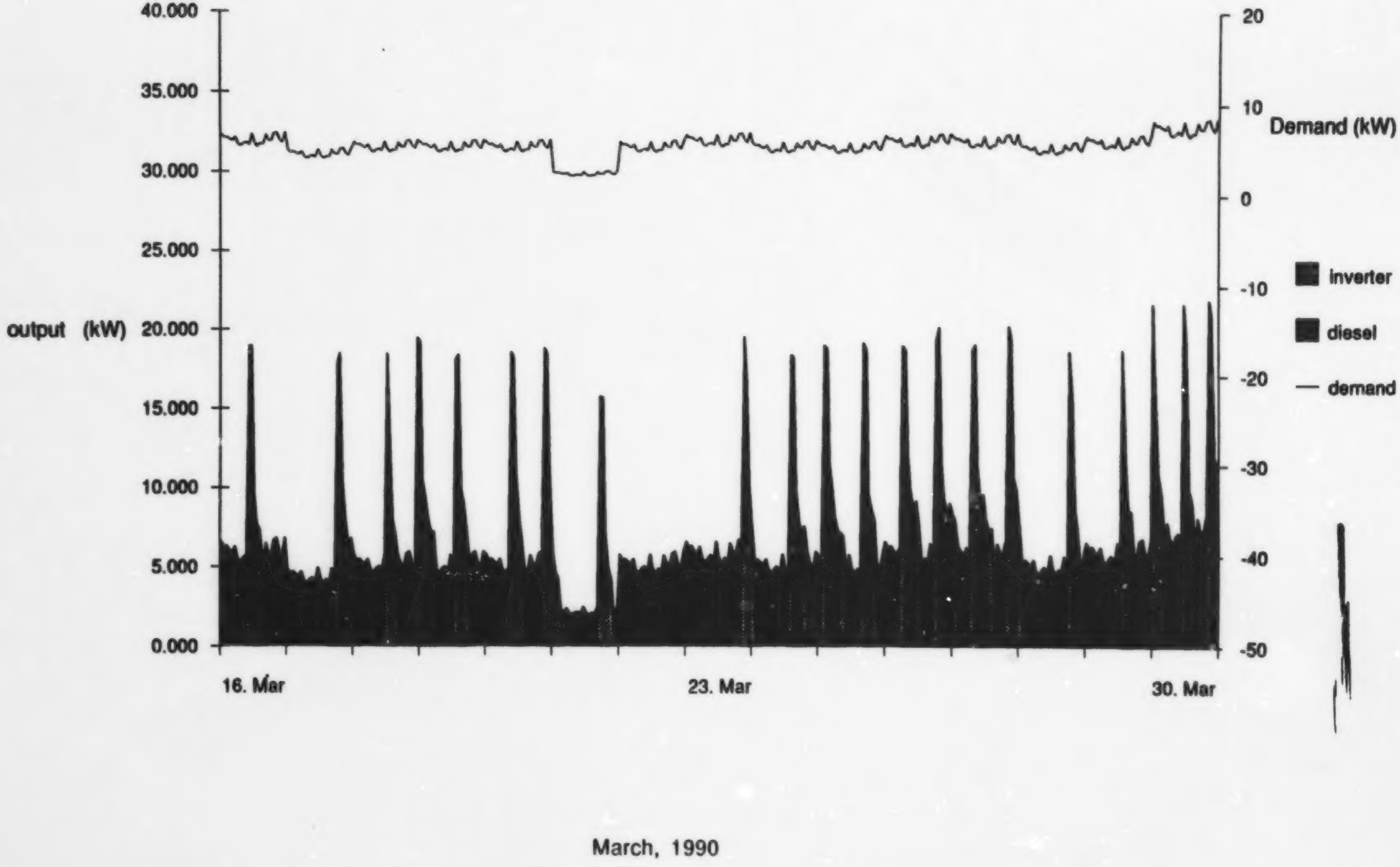
Hindcast Load History (1. Mar - 15. Mar)



March, 1990

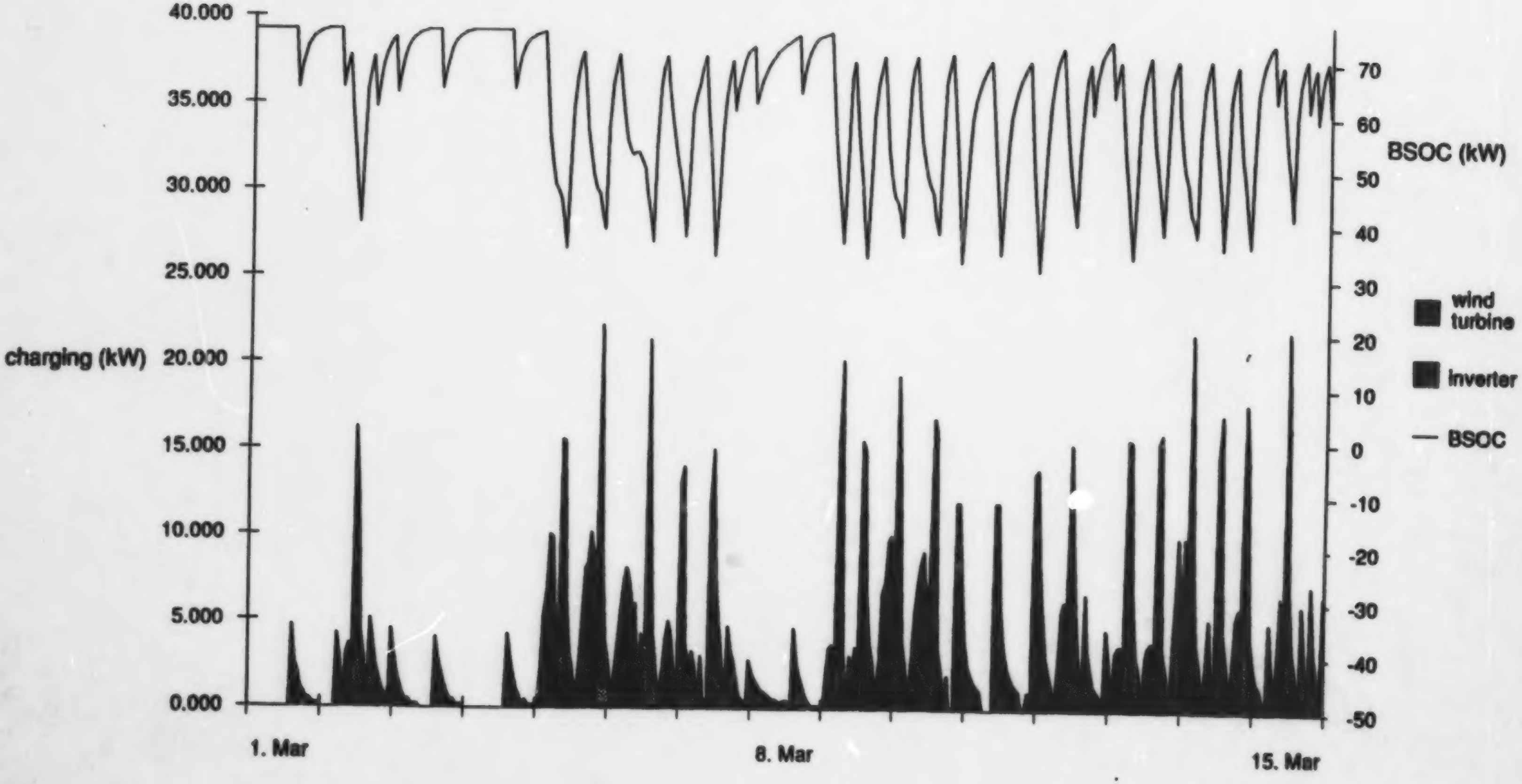
based on 60% of actual loads

Hindcast Load History (16. Mar - 30. Mar)



based on actual loads

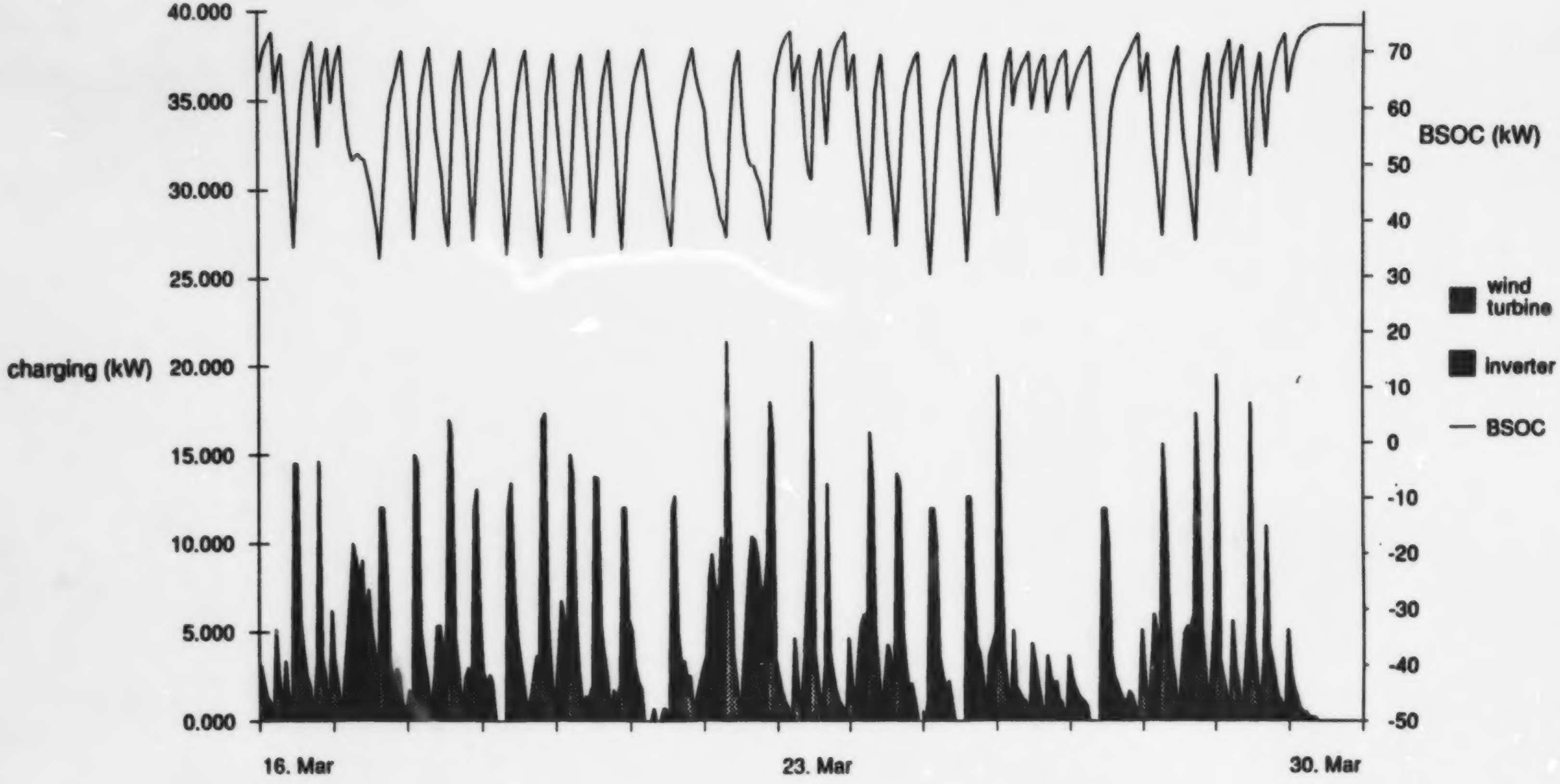
Hindcast Battery Charging History (1. Mar - 15 Mar)



March, 1990

based on actual loads

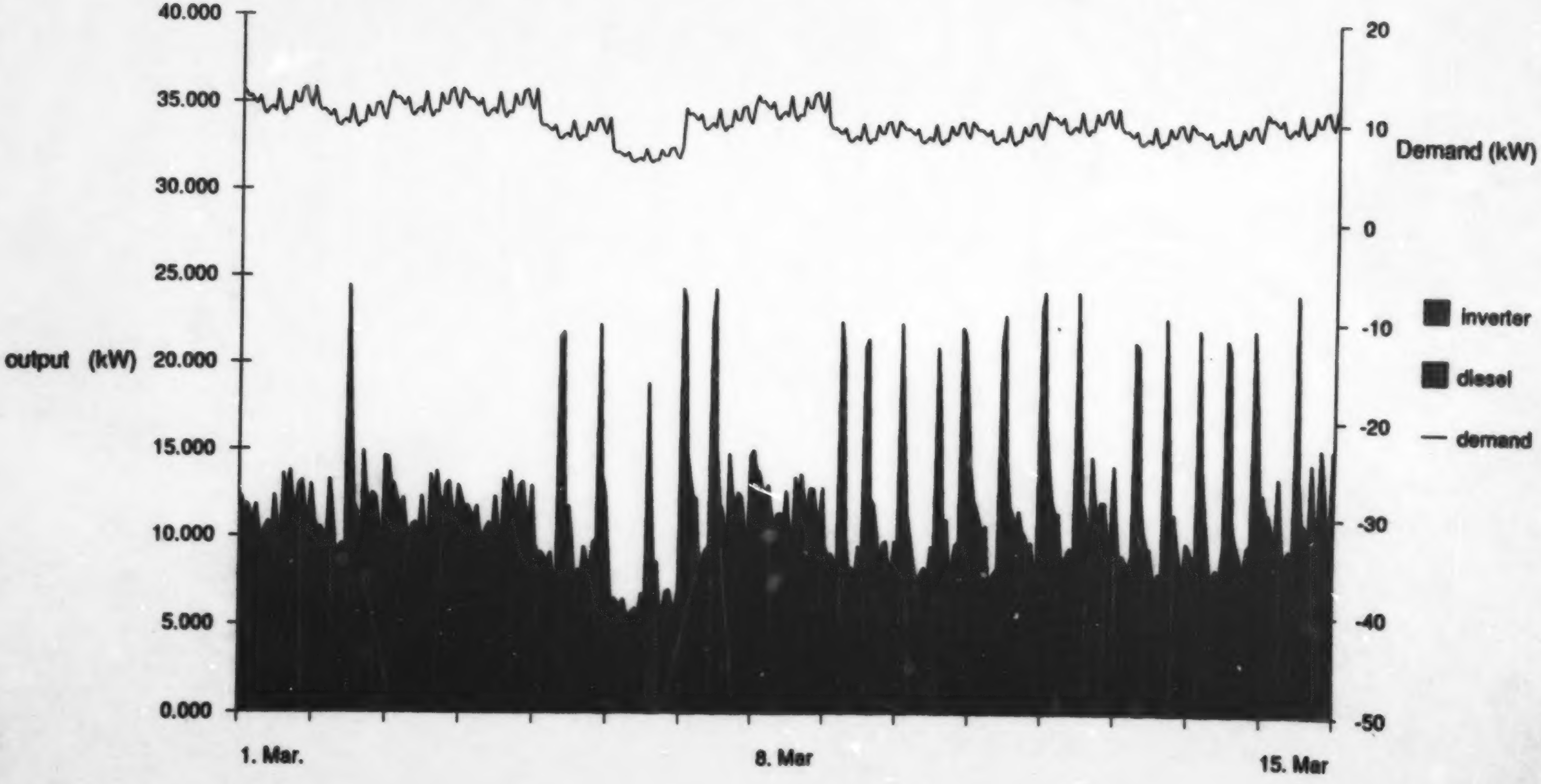
Hindcast Battery Charging History (16. Mar - 30. Mar)



March, 1990

based on actual loads

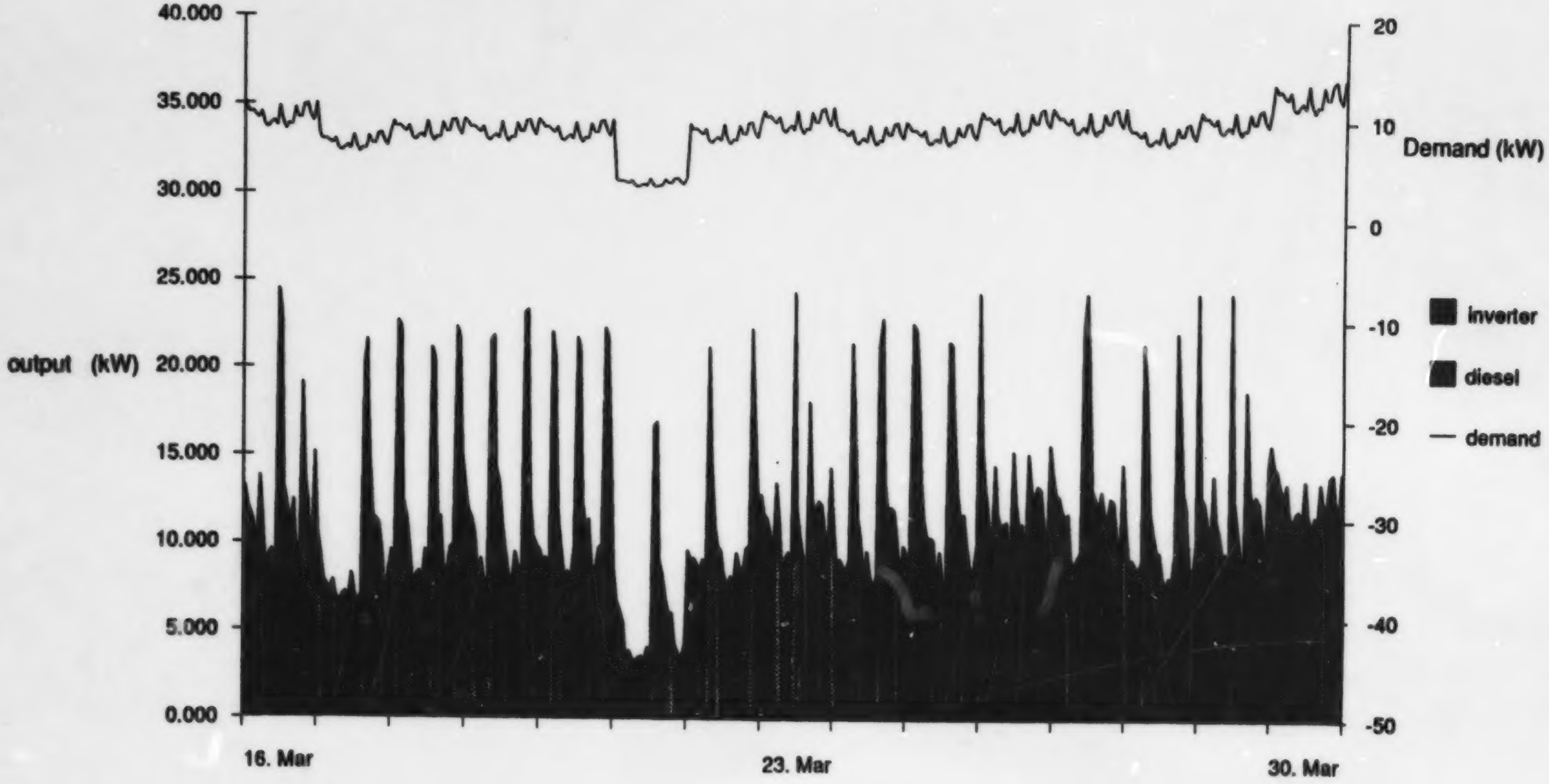
Hindcast Load History (1. Mar - 15. Mar)



March, 1990

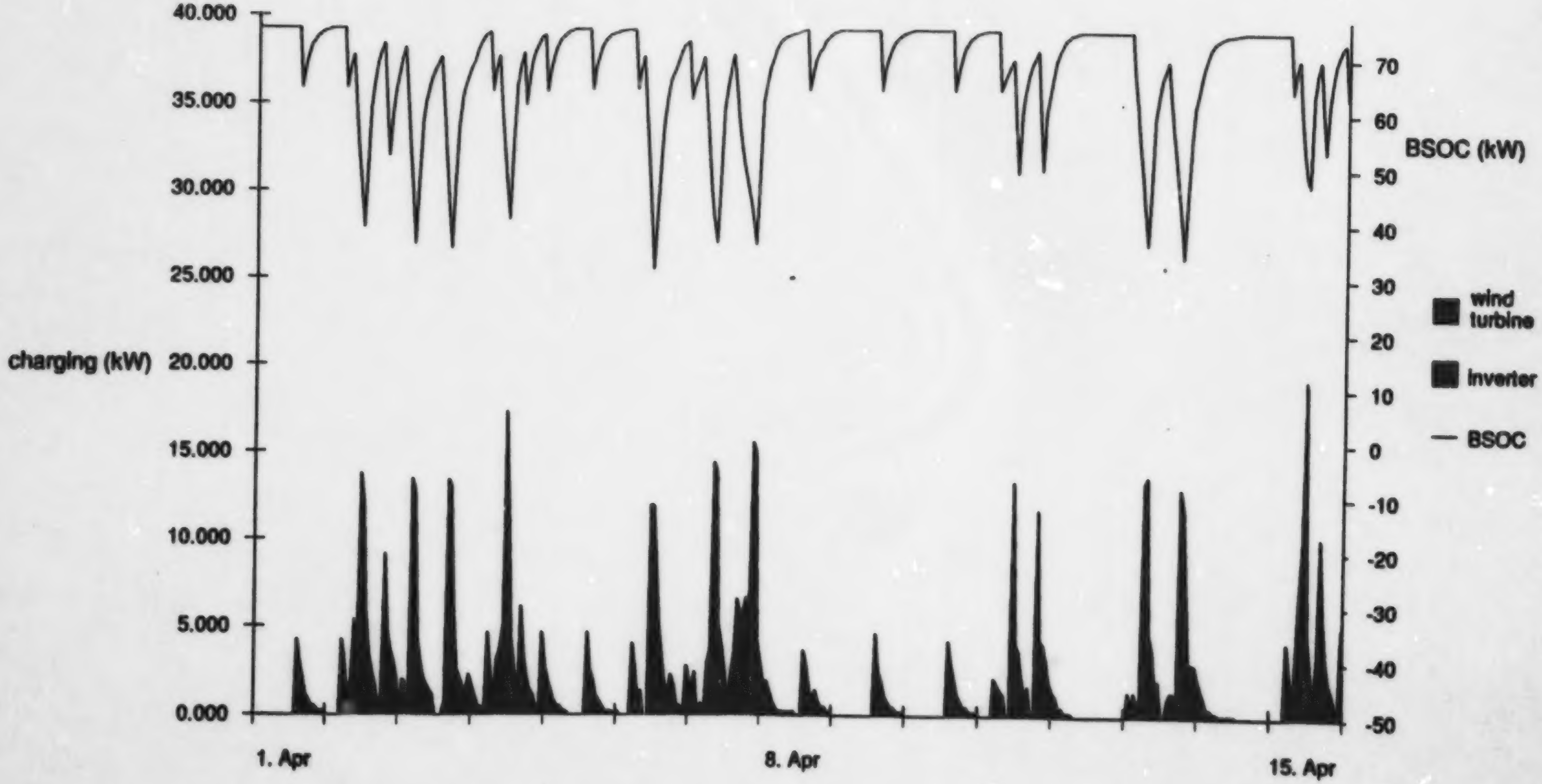
based on actual loads

Hindcast Load History (16. Mar - 30. Mar)



March, 1990

based on actual loads

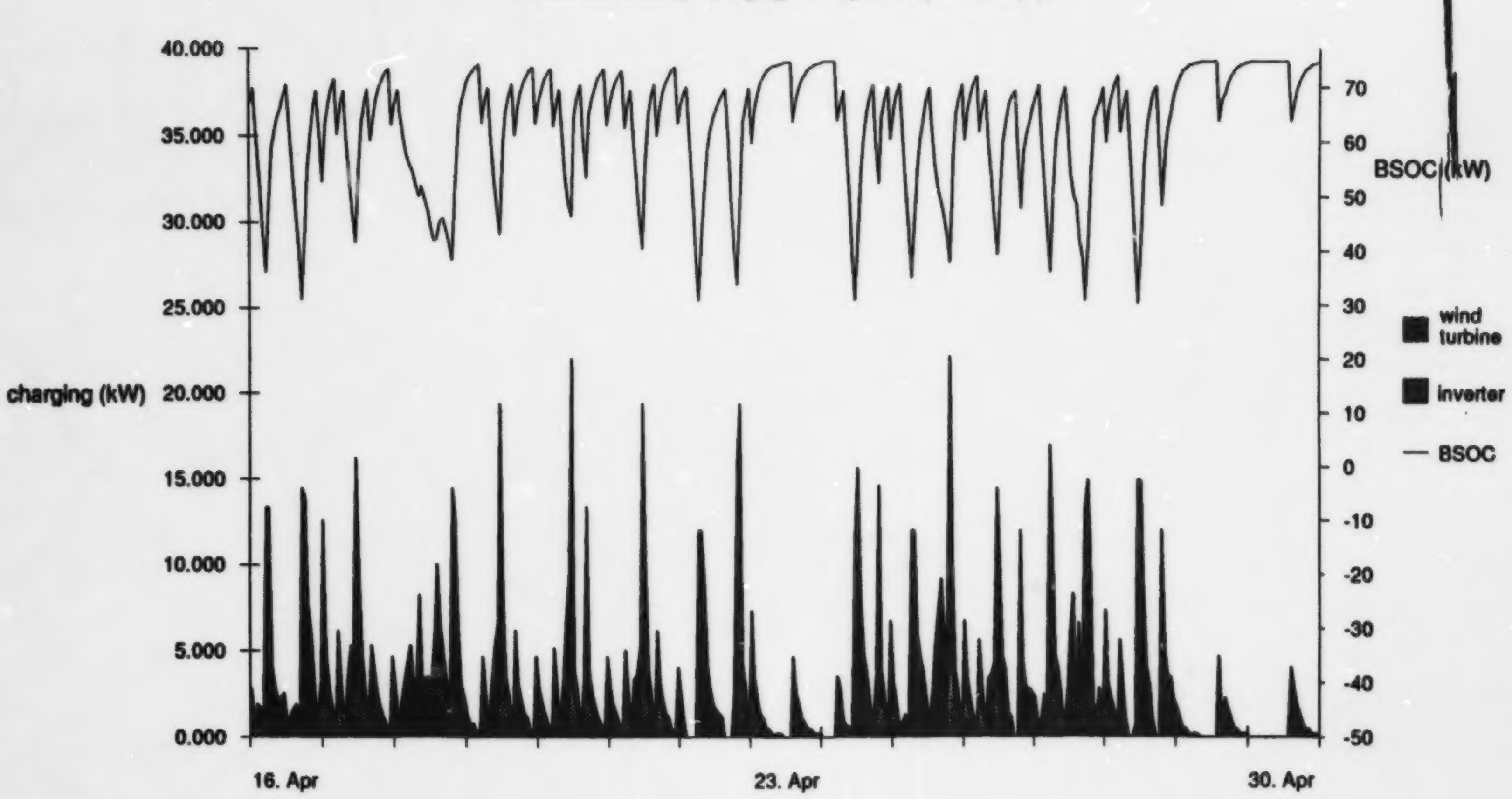


Hindcast Battery Charging History (1. Apr - 15. Apr)

April, 1990

based on actual loads

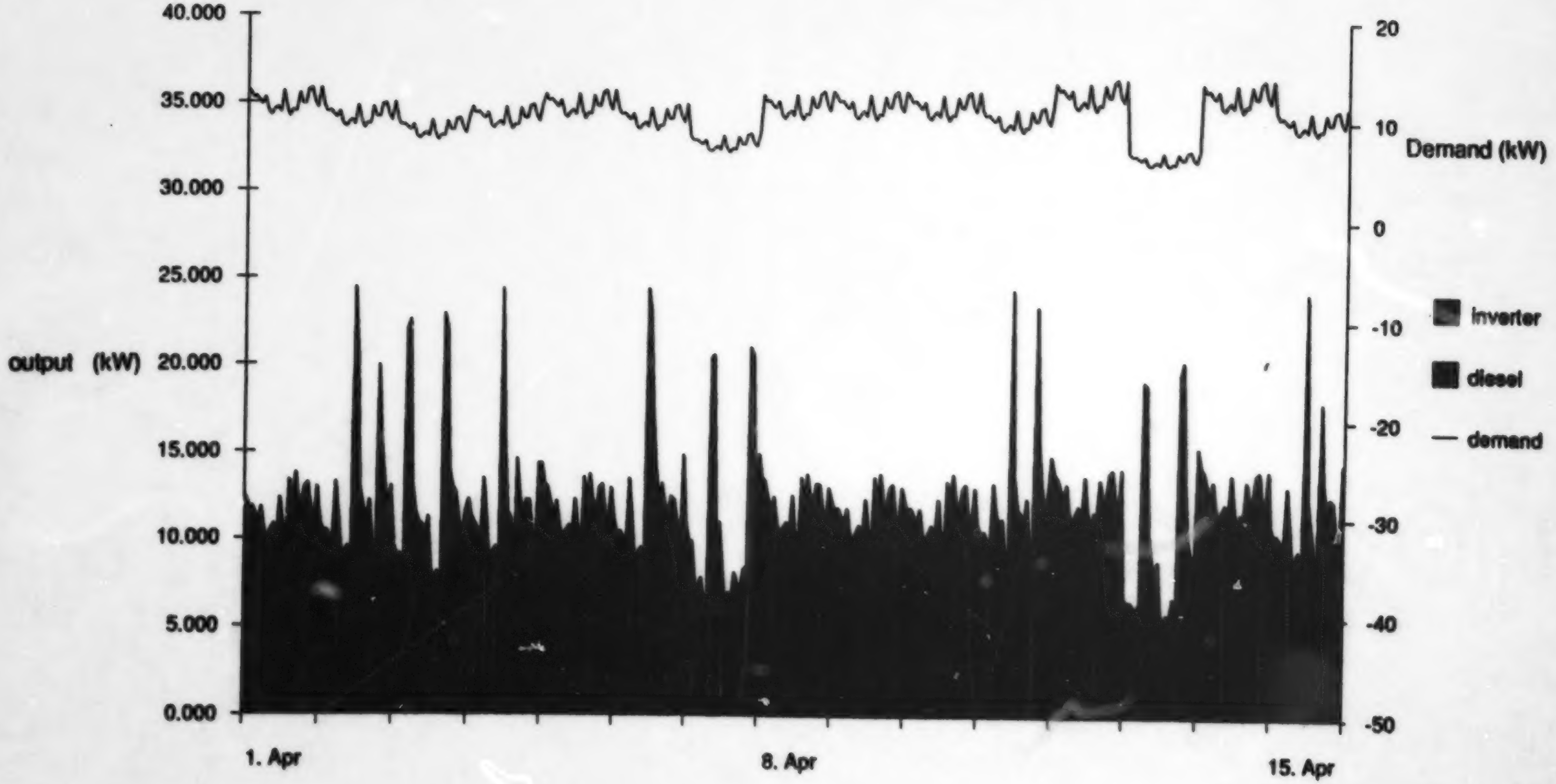
Hindcast Battery Charging History (16. Apr - 30. Apr)



April, 1990

based on actual loads

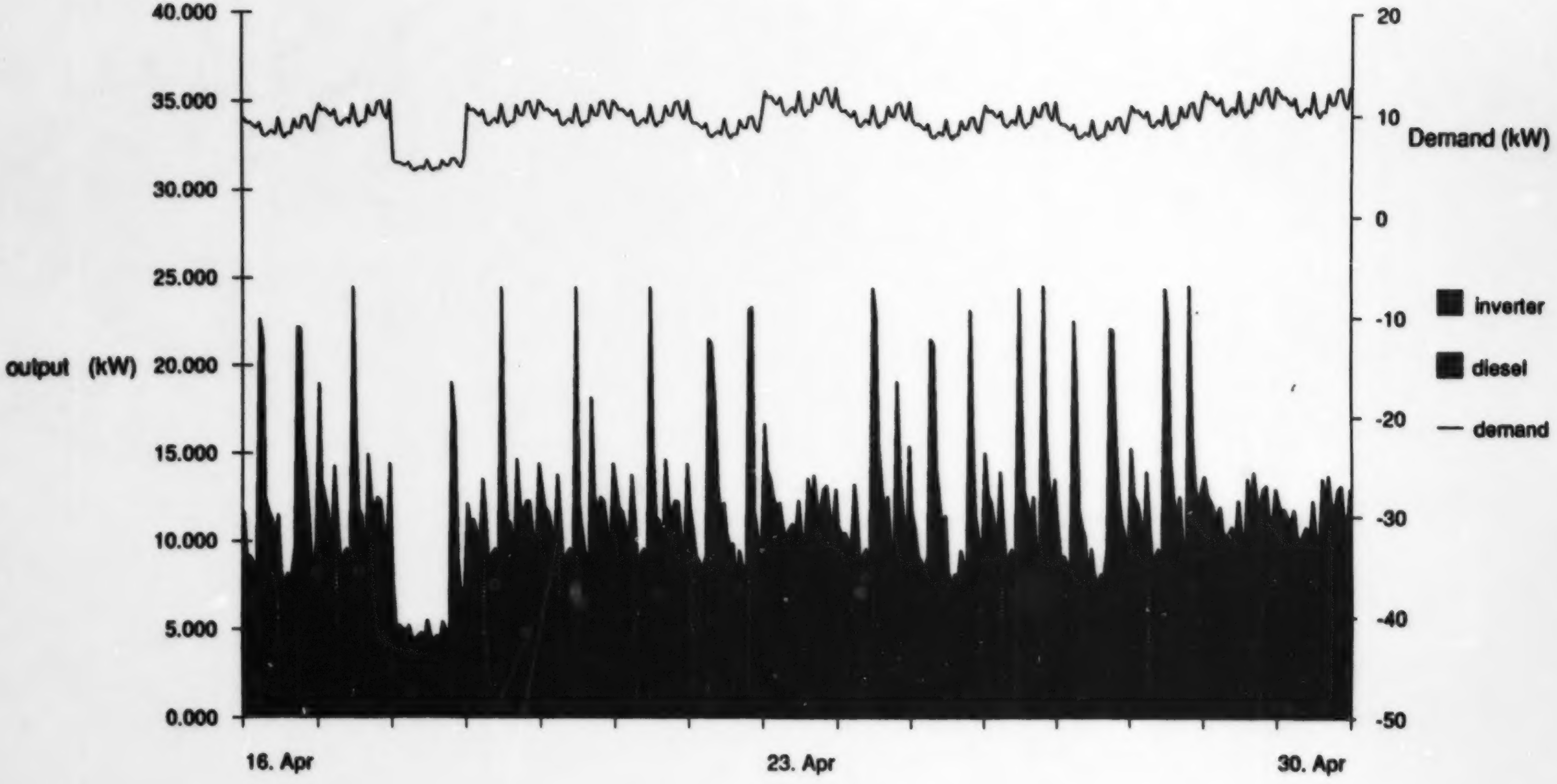
Hindcast Load History (1. Apr - 15. Apr)



April, 1990

based on actual loads

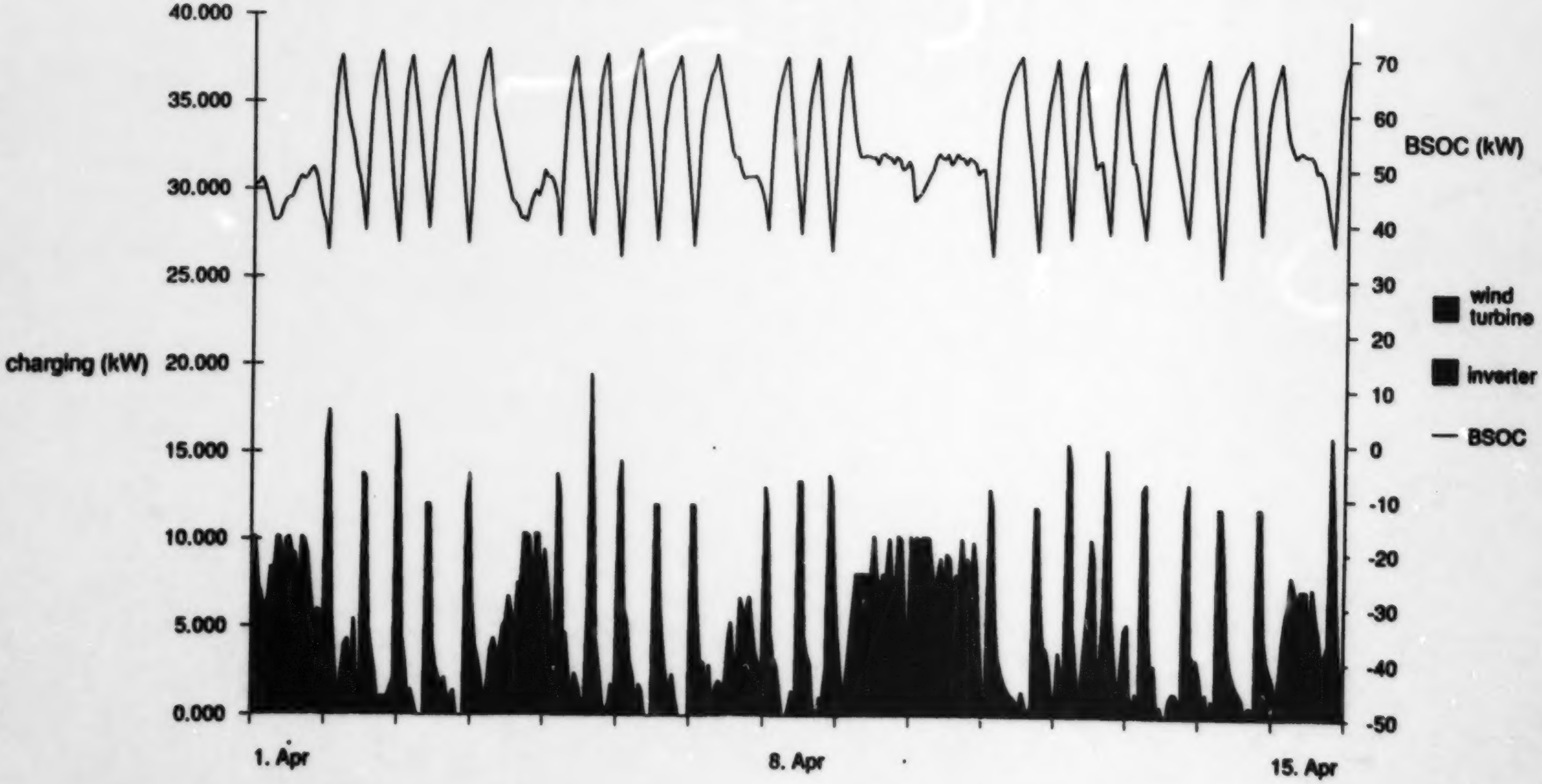
Hindcast Load History (16. Apr - 30. Apr)



April, 1990

based on 60% of actual loads

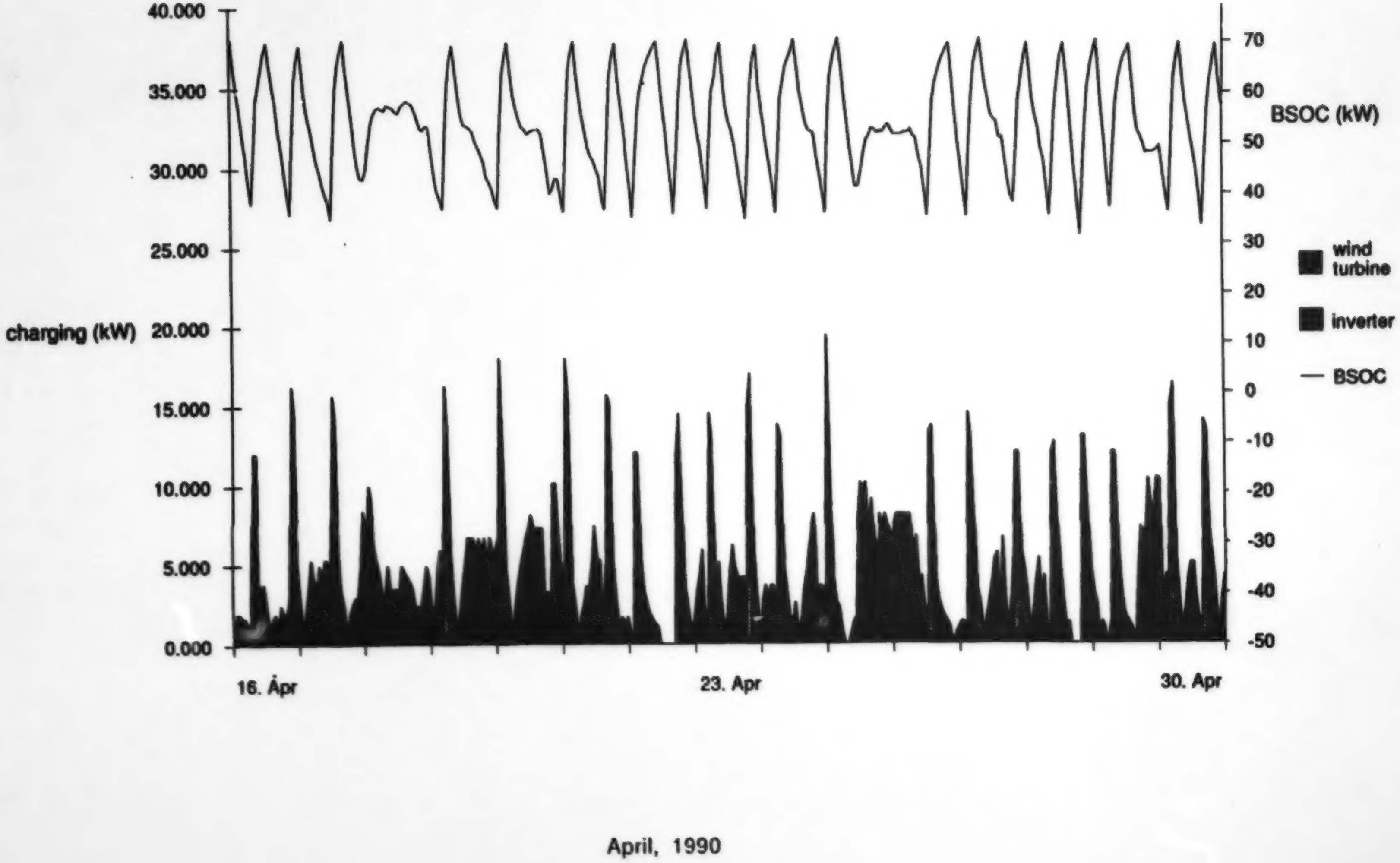
Hindcast Battery Charging History (1. Apr - 15. Apr)



April, 1990

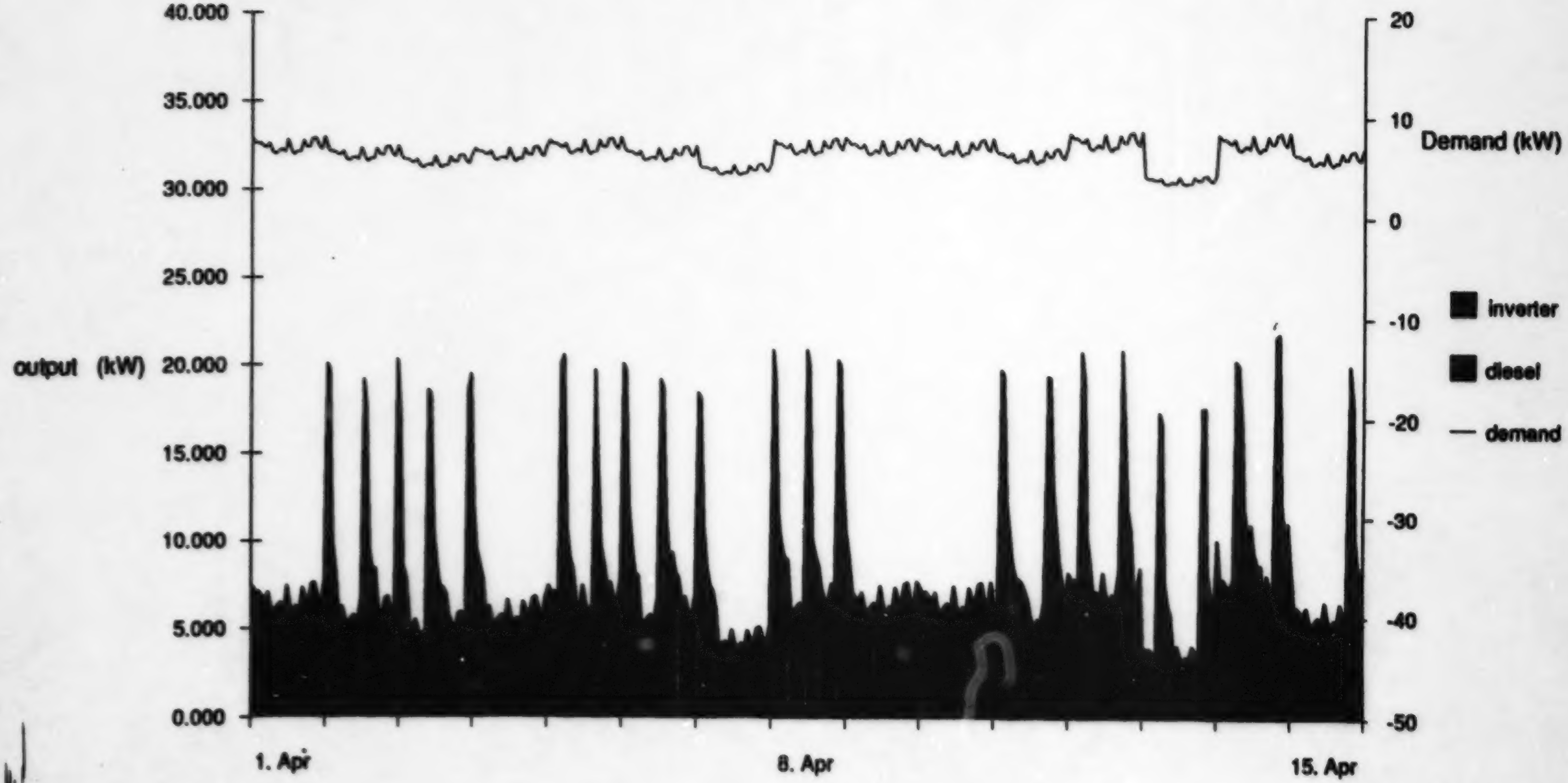
based on 60% of actual loads

Hindcast Battery Charging History (16. Apr - 30. Apr)



based on 60% of actual loads

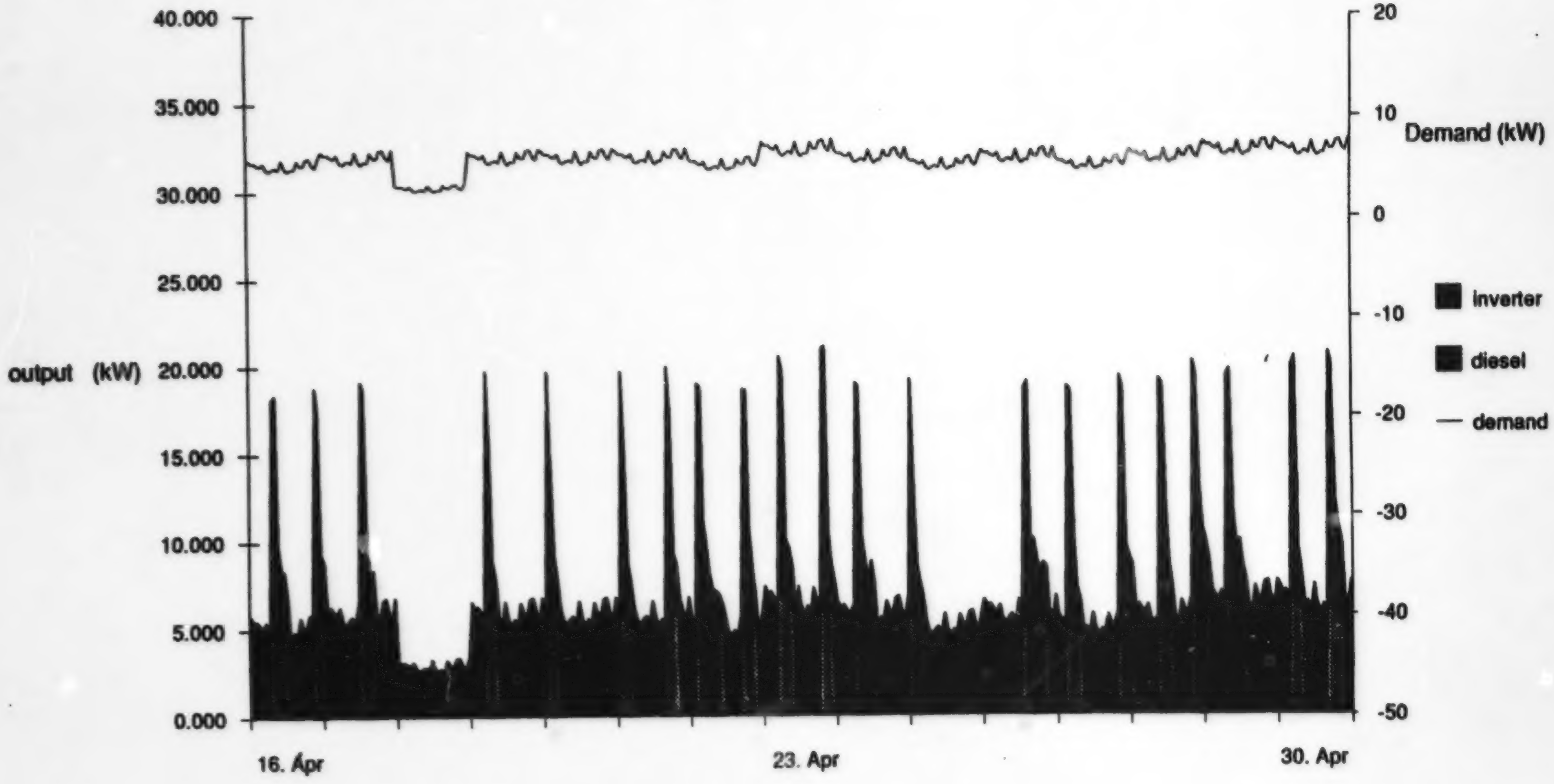
Hindcast Load History (1. Apr - 15. Apr)



April, 1990

based on 60% of actual loads

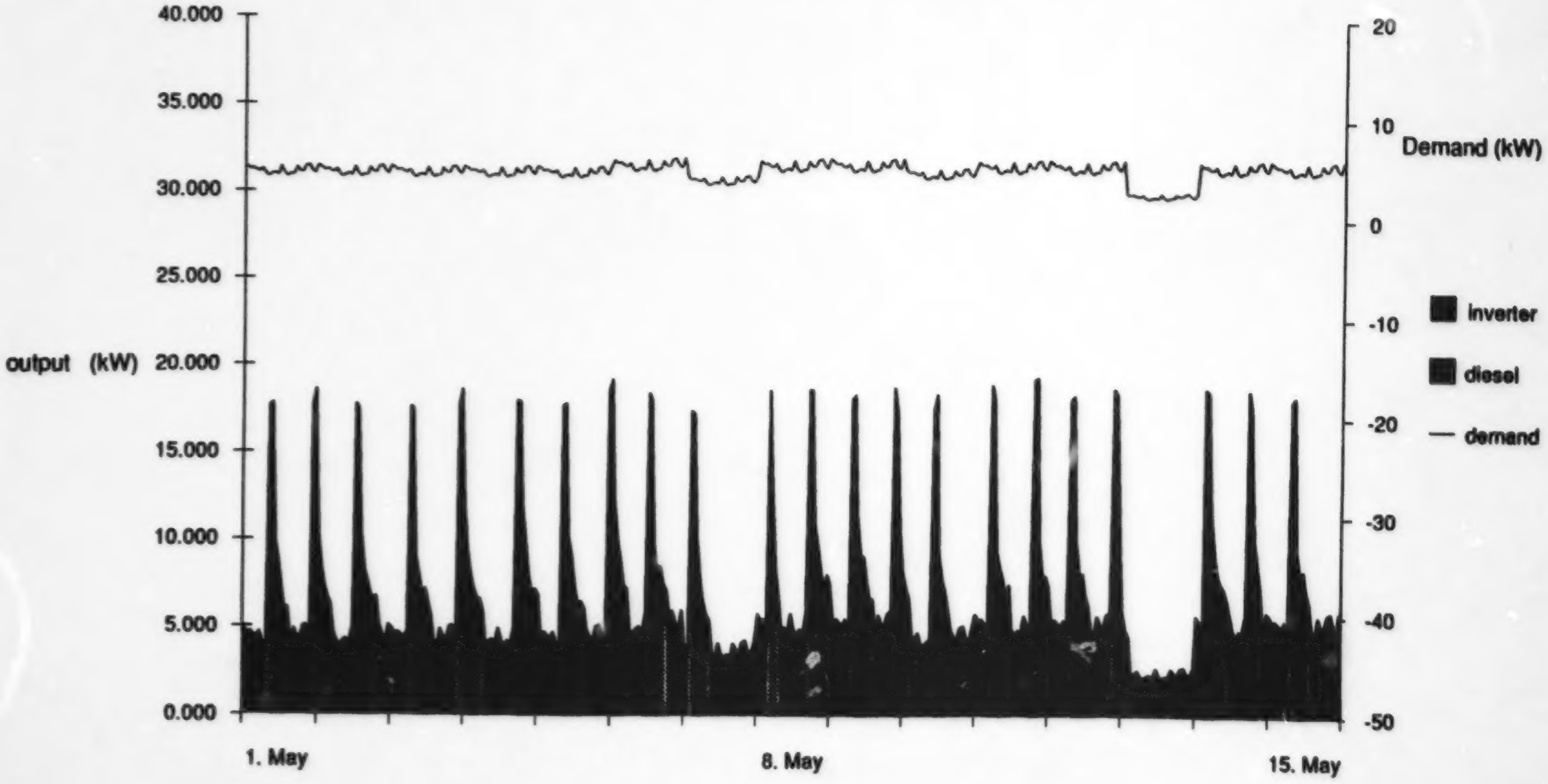
Hindcast Load History (16. Apr - 30. Apr)



April, 1990

based on 60% of actual loads

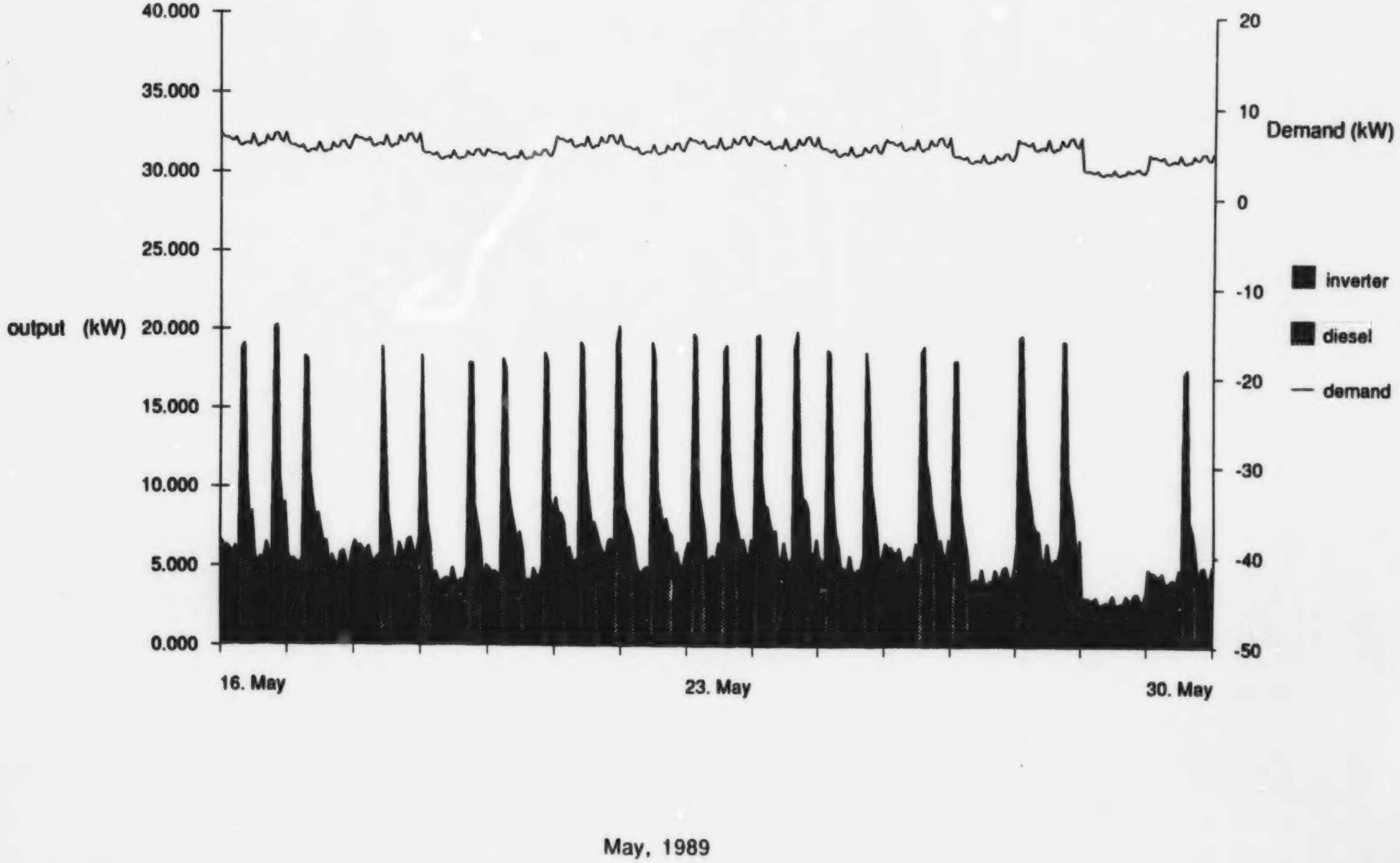
Hindcast Load History (1. May - 15. May)



May, 1989

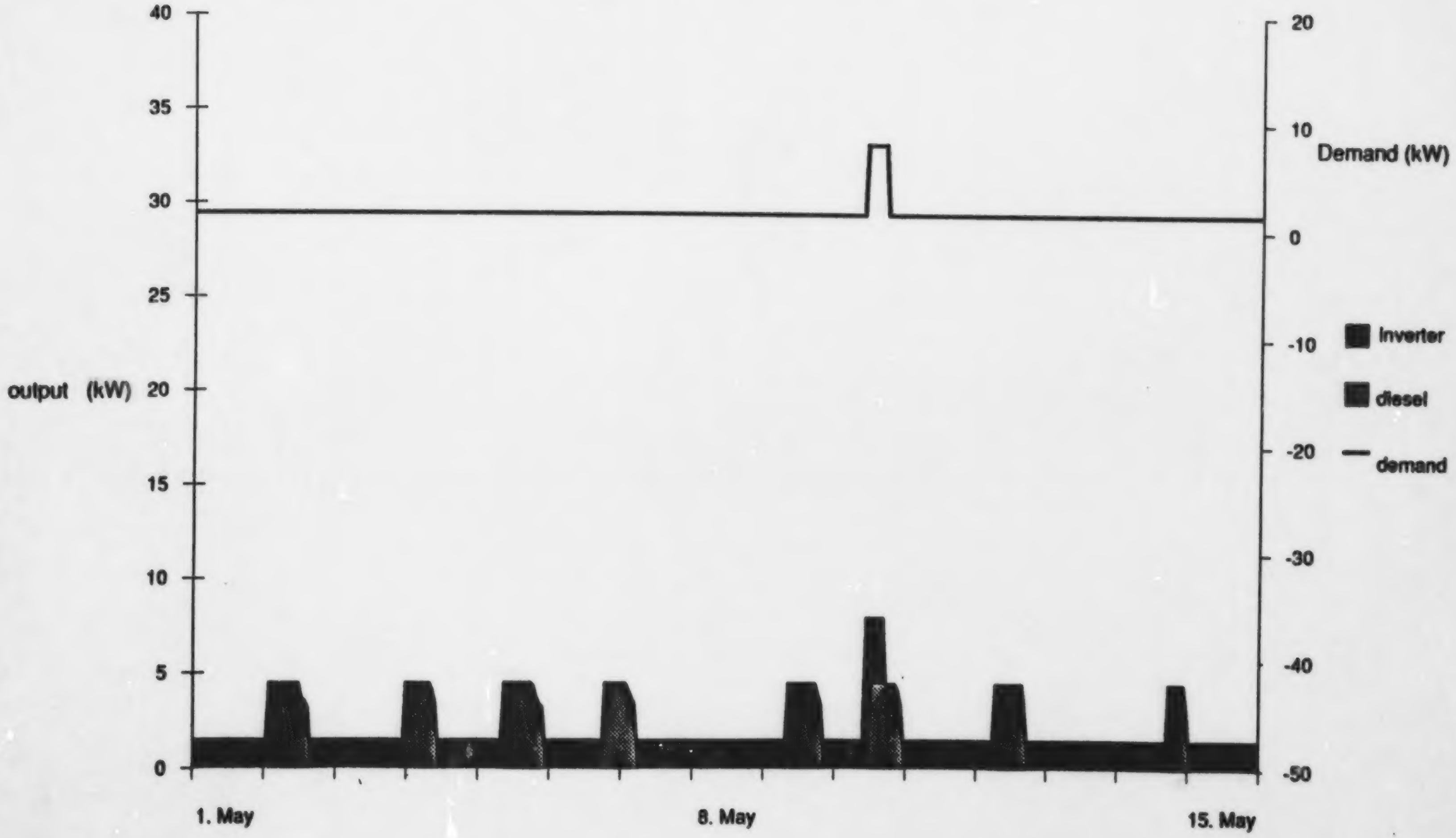
based on 60% of actual loads

Hindcast Load History (16. May - 30. May)



based on automatic station loads

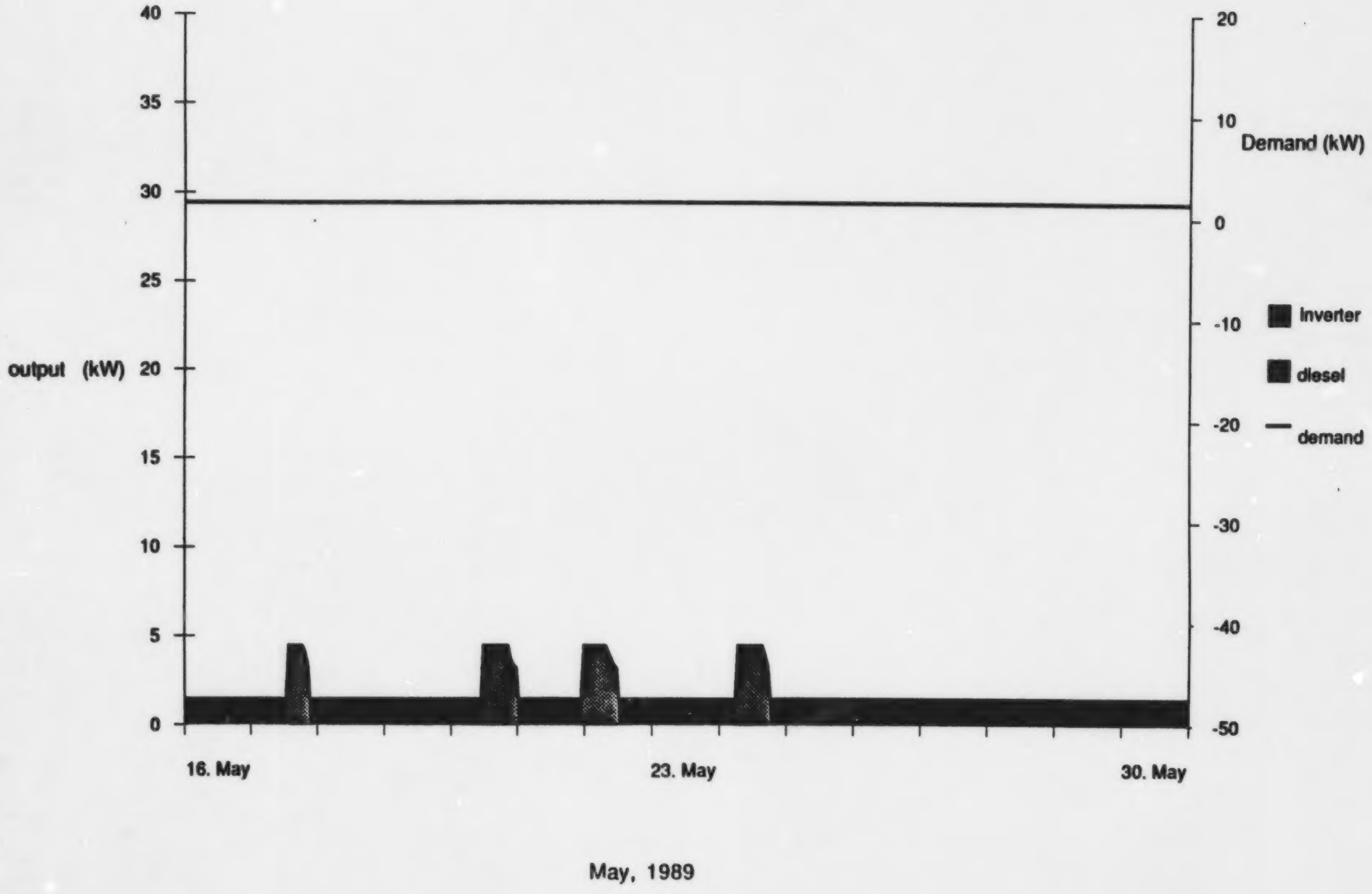
Hindcast Load History (1. May - 15. May)



May, 1989

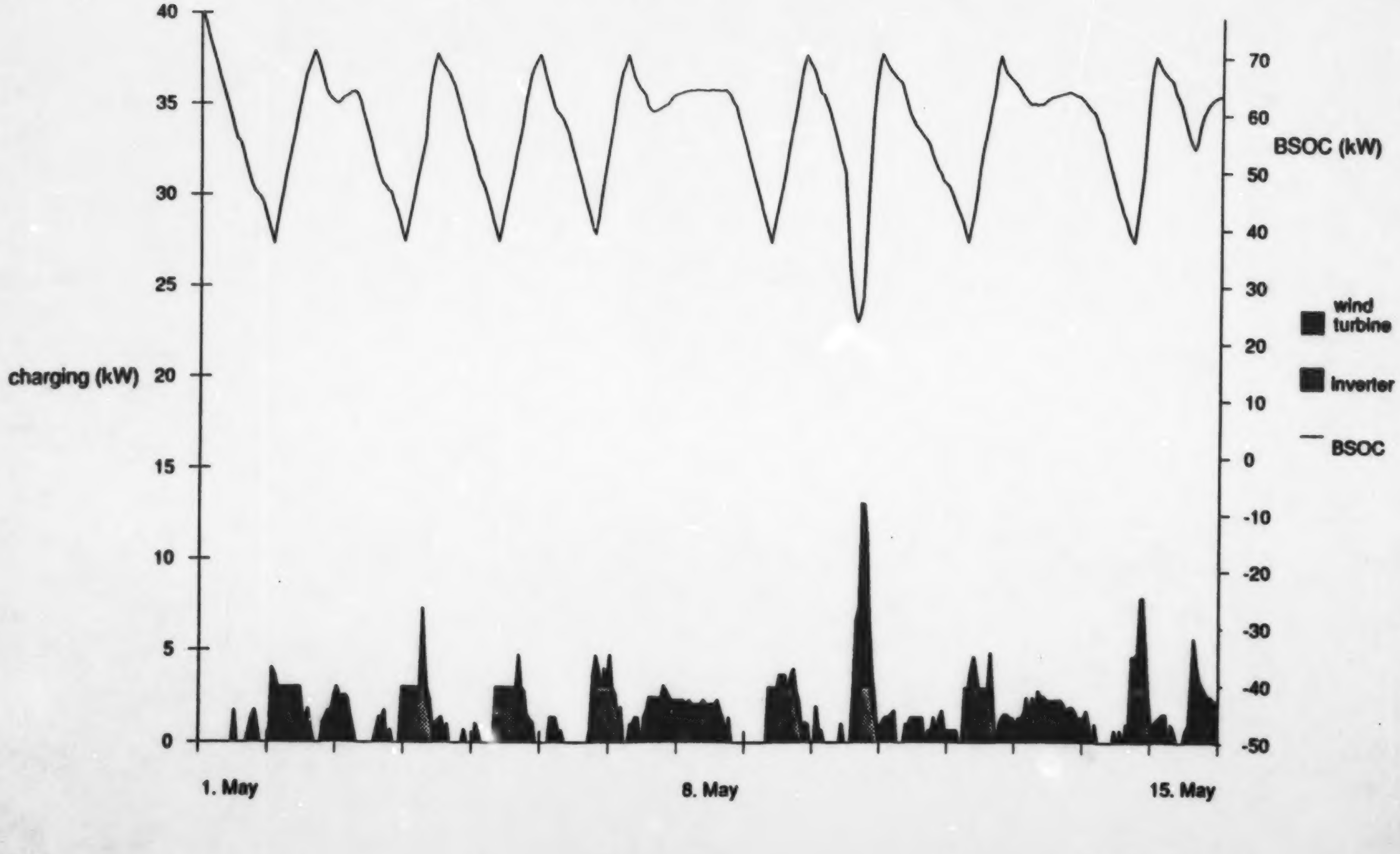
based on automatic station loads

Hindcast Load History (16. May - 30. May)



based on automatic station loads

Hindcast Battery Charging History (1. May - 15. May)



based on automatic station loads

Hindcast Battery Charging History (16. May - 30. May)